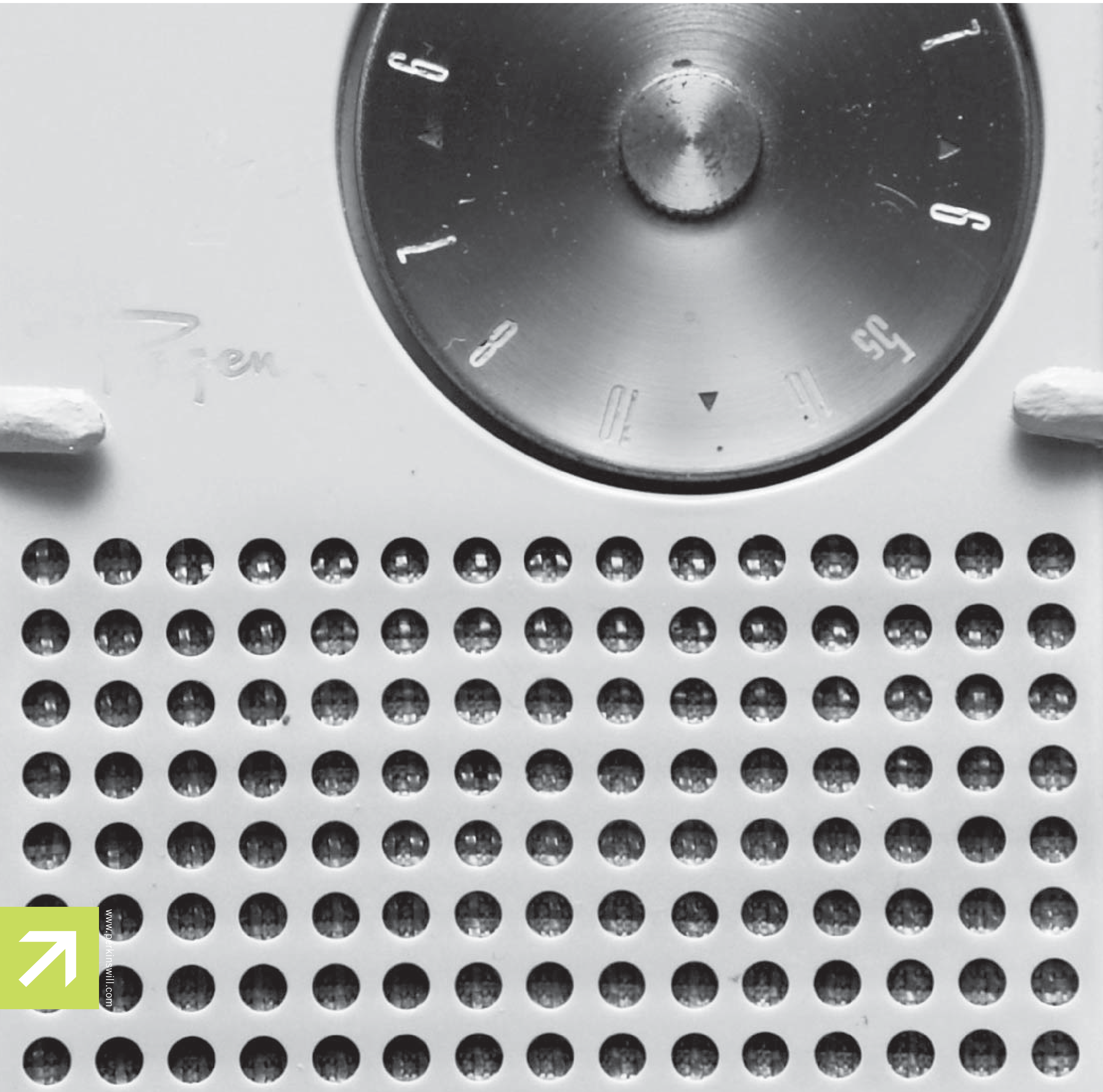
PERKINS+WILL

Research Journal

+↗
2009 / VOL 01.01



www.perkinswill.com

Editors: **Ajla Aksamija, Ph.D., LEED® AP and Kalpana Kuttaiah, Assoc. AIA, LEED® AP**

Journal Design & Layout: **Kalpana Kuttaiah, Assoc. AIA, LEED® AP**

Cover Design: **Mimi Day, AIGA**

Acknowledgements: **With much APPRECIATION** *to everyone who contributed in many ways to the research work and articles published in this journal.*

We would like to extend our **VERY SPECIAL THANKS** *to:*
Craig Graber, AIA, LEED® AP
Scott Yocom, AIA
Robin Guenther, FAIA, LEED® AP
Gavin Smith, AIA, CDT, LEED® AP
Jeffrey Saad, AIA, LEED® AP
Mark Walsh, AIA, CDT, LEED® AP
and
Emily Gartland

Perkins+Will is an interdisciplinary design practice offering services in the areas of Architecture, Interior Design, Branded Environments, Planning + Strategies and Urban Design.

PERKINS+WILL

Research Journal

2009 / VOL 01.01

TABLE OF CONTENTS

JOURNAL OVERVIEW

The Perkins+Will Research Journal is dedicated to documenting and presenting practice-related research associated with buildings and their environs. The aim of this journal is to capture and document research questions and methodologies that arise prior, during and after the design process. Original research articles, literature reviews, and case studies have been incorporated into this publication. The unique aspect of this journal is that it conveys practice-oriented research projects aimed at supporting our design teams.

This is the first issue of the Perkins+Will Research Journal. We welcome contributions for future issues.

RESEARCH AT PERKINS+WILL

Research is systematic investigation into existing knowledge in order to discover or revise facts or add to knowledge about a certain topic. In architectural design we take an existing condition and improve upon it with our design solutions. During that process we constantly gather and evaluate information from different sources and apply in novel ways to solve our design problems, thus creating new information and knowledge. An important part of the research process is documentation and communication. With this journal we are sharing combined efforts and findings of Perkins+Will researchers.

Perkins+Will undertakes the following areas of research:

- Market-sector related research in healthcare and science+technology
- Biomimicry and restoration of ecological systems
- Sustainable design
- Strategies for operational efficiency
- Advanced building technology and performance
- Design process benchmarking
- Policy research
- Carbon and energy analysis
- Organizational behavior

01.
BUILDING COMMISSIONING: STRATEGIES, CRITERIA AND APPLICATIONS

Ajla Aksamija, Ph.D., LEED® AP, *ajla.aksamija@perkinswill.com*

ABSTRACT
Building performance monitoring has a great potential to reduce energy usage through improved operation and maintenance. Enhanced functioning, lower energy costs, better indoor air quality and overall design satisfaction are some of the key benefits. However, in order to achieve these goals, successful transfer of design intent is required through all stages of design process and operation.

This paper discusses building commissioning, particularly focusing on capturing design intent throughout the project lifecycle. Building commissioning requires that users and facility managers fully understand design intentions, as well as interactions with prescribed building systems. Design representations and knowledge transfer become crucial in that aspect. Cost-implications, benefits, and roles of agents are discussed. Tools and applications aimed at facilitating the process are presented.

1.0 INTRODUCTION
Architecture, as a practice, relies on descriptions and representations of physical objects before their actual existence. Evaluation is necessary in order to compare the difference between the expected and achieved results. However that is a fairly complex procedure due to the discrepancies between building as a conception and building as a physical object. Isolated measurements with discrete objectives are the current typical method for evaluation, but the future goal is the persistent improvement of quality through continuous evaluation[1]. In order to achieve this goal, several prerequisites must be satisfied:

- Evaluation must be done systematically.
- Evaluation data must be organized and kept in a format usable for future use.
- Continuity of information must be present during different phases of a building's lifecycle.

Contribution from buildings toward global energy consumption is currently 40 percent[2]. Most of the energy usage in building is associated with building systems, particularly for the operation of heating, ventilation and air conditioning (HVAC) systems, which on average consume about 50 percent of building energy[3]. Evaluation of building systems and their performance is critical for reduced energy consumption.

Building commissioning is an important new area that promotes evaluation during several stages of the design process as well as operation and maintenance. Building commissioning has been made a prerequisite for Leadership in Energy and Environmental Design (LEED®) project delivery and certification, which has greatly increased awareness about this process. Projects following LEED guidelines are required to perform post-occupancy commissioning and additional points can be achieved by introducing comprehensive commissioning earlier in the design process.

Primary objective of commissioning is to evaluate building systems and verify design intent. During the early stages of the design, the commissioning process should be focused on balanced relationships between owner's requirements and design functionalities addressing these requirements. During the construction process, commissioning is focused on ensuring that the building agrees with the design specifications and intended functionalities. During the operation phase, the primary objective is to measure and verify that building performance is following design specifications. Continuous commissioning is also being advocated as a successful method for real-time monitoring and adjusting building performance based on operational requirements[4].

This paper is structured as follows: initially, cost-implications are briefly discussed to introduce benefits and associated costs. Methodologies for capturing design intent are discussed as well as roles of different agents during the process. Tools and applications, developed to assist documentation and the process, are lastly presented.

2.0 COST-IMPACT

Integration of building systems and their interdependencies in operation require coordination in design, construction and operation. Failure or deficiency of one component may influence the overall system affecting energy efficiency. Benefits of incorporating commissioning include energy and non-energy impacts and should be accounted for when assessing initial cost of commissioning process versus gained benefits over the building's lifecycle. Energy benefits are primarily associated with decreased operating costs, while non-energy benefits include improved indoor air quality, system reliability, building operation and maintenance and improved occupant comfort[5].

Recent study on cost-effectiveness of the building commissioning process has found that for new buildings, median commissioning costs are $1.00/SF, ranging from $0.49 to $1.69, depending on the size of the facility[6]. Median percentage of the total construction cost is 0.6%, ranging from 0.3% to 0.9%. Median payback time for the initial cost is 4.8 years, ranging from 1.2 years to 16.6 years, depending on the facility size, initial cost and energy savings.

Relative costs, energy savings and projected payback time also depend on the building type. Energy intensive facilities, such as laboratories, hospitals and higher education facilities tend to have larger energy savings associated with the commissioning process as well as lower average payback time. Commercial facilities, such as offices and retail, also have lower payback time.

3.0 STRATEGIES AND CRITERIA: PERFORMANCE METRICS

Commissioning originated in the naval industry, where constructed ships were tested for flaws and deficiencies prior to joining fleets. In the building industry, commissioning was adopted during the 1970s as a method for testing functionality of building systems and equipment prior to occupancy. Reasons for adoption were that advanced technologies and sophisticated building systems were implemented, requiring that all building systems functioned properly. American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) initiated development of guidelines for building commissioning of HVAC systems in 1984, with the intent to develop a process framework for evaluating systems prior to occupation. The resulting document, revised in 1996 and 2007, defines commissioning as the process of ensuring that HVAC systems are designed, installed, functionally tested and operable in conformity with the design intent and owner's requirements[7]. ASHRAE developed a guideline for the overall commissioning process in 2005, which provides direction for evaluation of design and systems in new buildings, such as fire and life safety, roofing systems, HVAC, electrical distribution and emergency power, controls and communications systems. The commissioning process, according to this guideline, is defined as a "quality-oriented process for achieving, verifying and documenting that the performance of the facilities, systems and assemblies meets defined objectives and criteria"[8].

Documents essential for building commissioning are Design Intent, Basis of Design and Commissioning Plan[9]. Design Intent captures owner's requirements and should provide metrics and measurable objectives that can be utilized to develop Basis of Design functionalities. Clearly defined performance criteria for temperature levels, lighting, internal air quality and energy consumption are recommended. Commissioning Plan identifies the organizational structure of the process during different design phases and should identify roles of different agents. It is a communication tool between the owner and the commissioning authority, outlining the planning and scheduling of evaluations and tests.

Design Intent should capture operational goals by stating an objective, strategy and associated quantitative performance metrics. Objectives are qualitative statements reflecting desired performance and metrics are variables that can be utilized to measure objectives. Strategies are ways for implementation in the design. Performance metrics should be measurable, have a clear definition and boundaries of the measurements and indicate progress toward operational goals[10].

Capturing and preserving this information across the lifecycle of the building ensures that:

- Participants in the project can clearly document desired performance objectives during initial planning
- Evaluations of the proposed designed options are supported and the decision making process relies on evaluation results
- Evaluations are shared among the design agents
- Commissioning process is well supported and cost-effective
- Performance measurement and verification are supported in a structured manner.

Example of this method is presented in Figure 1. Owner's goal requiring an energy-efficient building should be utilized to develop performance objectives, such as “Minimizing Lighting Load” or “Minimizing Heating Load”. These goals are the basis for developing design strategies as well as performance metrics when applicable.

Multiple qualitative goals can be expressed for energy efficiency, environmental impact and overall functionality. From the qualitative goals, implementation strategies can be developed to address particular goals by the actual design. Performance metrics, expressed in quantitative manner, can be utilized to set objectives that can be predicted, tested, measured, verified and monitored during the building lifecycle.

4.0 IMPLEMENTATIONS: PROCESS AND ROLES OF AGENTS

Commissioning process is initiated by the owner and the methodology depends on the time when Commissioning Authority is introduced in the overall design process. Post-construction commissioning is a one-time evaluation of building systems that occurs prior to occupation. Improved methodology is commissioning during several stages of the design process, which indicates that Commissioning Authority is involved from the early start. The last form is continuous commissioning, which monitors performance through a form of Building Energy Management System (BEMS). Table 1 summarizes characteristics and properties of these different types.

Roles of agents depend on the utilized type of process. There are similarities in the overall structure, however, the amount of involvement highly depends when the Commissioning Authority is introduced. In the case of post-construction commissioning, Design Intent Documentation (DID) is developed by the owner with input from the design team and consultants as well as facility managers and occupants. During the design phase, the architect develops Basis of Design (BOD) documentation that should respond to DID and owner’s requirements. Commissioning Authority is usually introduced close to the end of construction phase where commissioning plan and schedule should be prepared. These documents are used as a basis for testing procedures, which are performed prior to occupation. Design projects that are seeking LEED certification must perform this basic process, but the involvement of the Commissioning Authority should begin at the design development phase since review of DID and BOD is required. Commissioning Authority prepares final reports, which outlines test procedures, data reports and records for LEED documentation.

Comprehensive commissioning involves Commissioning Authority from the pre-design phase and requires enhanced collaboration and communication between

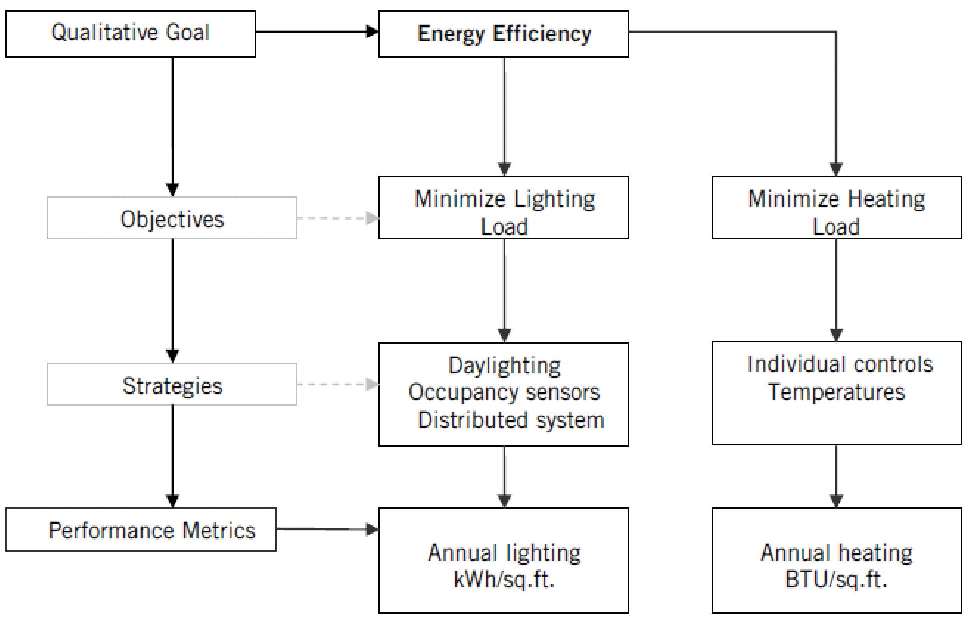


Figure 1: Method for capturing design intent through establishment of objectives, strategies and performance metrics.

agents. Table 2 presents matrix of roles and responsibilities during pre-design and design stages of the process while Table 3 shows construction and occupancy/operation phase. Dependencies between procedures are indicated. Additional commissioning for LEED requires reviews during design developments and construction documentation as well as operation manual and post-occupancy testing.

The benefits of comprehensive commissioning is that collaboration from the earliest stages of the design as well as reviews during design development and construction documentation result in early detection of flaws and issues. Due to the growing complexity of building design and systems, energy savings are obtainable through optimal control, early detection and correction of faults and enhanced equipment performance.

5.0 TOOLS AND APPLICATIONS

There are several existing tools and applications developed for assisting in capturing design intent and documentation of the commissioning process.

Lawrence Berkeley National Laboratory developed a database tool that provides a structured approach for recording Design Intent based on operational goals, objectives, strategies and metrics[11]. The major advantage for using this tool is that owners and designers can plan, monitor and verify that the requirements are being met during each stage of the design process and Commissioning Authority, facility managers and future owners can understand the building, its systems and the intended operation. This is usually owner-driven process; however, collaborative involvement of all involved agents is beneficial. Area included in this application are general requirements; mechanical for ventilation systems, chiller plants and heating plants; electrical for lighting system, distribution system, and renewable sources; process for loads and operation and maintenance. Documentation templates for LEED projects are included in the application.

California Commissioning Collaborative (CCC) provides tools and resources to assist commissioning process for building owners and commissioning authority[12]. Useful templates include planning documents, such as scope of work, commissioning plan, log and systems manual. For example, guidelines for setting up the Design Intent include set of questions that should lead the process, such as the functional type of the facility and its

Table 1: Commissioning process types and characteristics.

TYPE	CHARACTERISTIC
Post-Construction	Applies to small and medium scale buildings. Involves one time checks and testing of building systems after construction. Performed by Commissioning Authority who may be part of Owner's or Construction Organization.
LEED Prerequisite E1	Involves one time checks and testing of building systems, but should begin at the design development phase. Commissioning Authority must review Design Intent documentation and Basis of Design.
Comprehensive	Applies to medium to large scale buildings. Begins early in the project. Requires independent Commissioning Authority. Requires design development review. Testing and verification performed after construction. Reports and operation manuals needed.
LEED Credit E 3	Similar to comprehensive commissioning process. Requires design development review, review of construction documentation, and submittals. Operation manual and post-occupancy commissioning are required.
Continuous	Requires constant monitoring of building performance during operation.Involves automatic or manual measures of energy usage and system performance and comparison to final Design Intent metrics. Involves functional performance testing during construction, and fault detection and diagnostics during operation.

	Owner	CA	Design Team					Consultant	Contractors		Specialists		Building Operators		
	Owner, Owner's Representative	*Commissioning Authority*	*Architect*	*Structural Engineer*	*Mechanical Engineer*	*Electrical Engineer*	*Interior Design Professional*	*Consultants*	*General Contractor*	*Subcontractors*	*Indoor Air Quality Specialist*	*Acoustic Specialist*	*Facility Manager*	*Facility Engineer*	*Occupants*
PRE-DESIGN															
Design Intent Documentation (DID)	P	R	I	I	I	I	I	I					I	I	I
Allocation	P	U	U	U	U	U	U						I	I	
Commissioning plan	A	P	I	I	I	I							I	I	I
Log and report	R	P	U	U	U	U		I	U	U					
Acceptance and commissioning process report	R	P	U	U	U	U		U	U	U			U	U	
DESIGN															
DID Update	A	P	I	I	I	I		I			I		I	I	I
DID-Schematic design phase	A	P	I	I	I	I		I			I	I	I	I	I
DID-Design development phase	A	P	I	I	I	I					I		I	I	I
DID-Construction documentation phase	A	P	I	I	I	I		I			I		I	I	I
Basis of Design (BOD)	A	R	P	I	I	I					I		I	I	I
BOD-Schematic design phase	A	R	P	I	I	I					I	I	I	I	I
BOD-Design development phase	A	P	I	I	I	I		I			I		I	I	I
BOD-Construction documentation phase	A	P	I	I	I	I		I			I		I	I	I
Updated commissioning plan	R	P	U		I	I		U					I	I	
Construction specifications for commissioning	R	P	U					I	U	U			U	U	
Systems manual outline	A	P	I	I	I	I							U	U	
Commissioning-Focused design review	A	P	U	U	U	U						I	I	I	I
Log and report	A	P	U	U	U	U		I	U	U		I	I	I	I
Acceptance and commissioning process report	A	P	U	U	U	U		I				I	I	I	I

Key
P Provided by
A Approved by
R Reviewed by
I Input from
U Used by

Table 2: Roles and dependencies between agents during comprehensive commissioning process (pre-design and design)[13].

	Owner	CA	Design Team					Consultant	Contractors		Specialists		Building Operators		
	Owner, Owner's Representative	Commissioning Authority	Architect	Structural Engineer	Mechanical Engineer	Electrical Engineer	Interior Design Professional	Consultants	General Contractor	Subcontractors	Indoor Air Quality Specialist	Acoustic Specialist	Facility Manager	Facility Engineer	Occupants
CONSTRUCTION															
Pre-bid commissioning briefing	R	R	I					I				I	I		
Commissioning plan and inspection checklists update	R	U	I		I	I		I	U	U		I	I		
Pre-construction commissioning process briefing	A	P	I					I	U	U		I	I		
Submittal review comments	R	P	I		I			I	U	U		I	I		
Commissioning schedule	R	P	I					I	U	U		I	I		
Test procedures	A	P	I		I	I		I	U	U	I	I	I		
Test data reports	A	P	I					I			I		I		
Commissioning meeting record	A	P	R					R	U	U	R	R	R	R	
Site visit record	A	P	R					R	R	U	R	R	R	R	
Training plans	R	R	I		I	I		I	U	U	I		A	R	
Construction phase commissioning process report	A	R	I					I	U	U	I		R	R	
Systems manual update	A	P	I		I	I		I	I	I	I		R	R	
Log and report	R	P	U					I	U	U	I		I	I	
BOD update	R	P	P			I		I	U	U	I		I	I	
Construction phase acceptance and commissioning process report	A	P	R					I	U	U	I		I	I	
OCCUPANCY AND OPERATION															
DID Compliance update	A	P	R					I	R	I	I		A	R	
Testing record	A	P	R						R		I		A	R	
Acceptance and commissioning process report	A	P	R						U	U	I		A	R	
System manual update	A	P	I		I	I			I	I			A	R	

Key

P	Provided by
A	Approved by
R	Reviewed by
I	Input from
U	Used by

Table 3: Roles and dependencies between agents during comprehensive commissioning process (construction and occupancy/operation)[13].

requirements, types of equipments, occupant comfort and thermal conditions and methods for operational benchmarking.

Energy Design Resources (EDR) hosts a web-based application Commissioning Assistant, useful for providing project-specific information to the design teams[14]. Basic functions include evaluation of the probable commissioning cost, identification of the scope and development of documents, Design Intent and Basis of Design documentation, commissioning specifications, sequence of operations as well as training plan and systems manual.

6.0 CONCLUSION

This paper reviews commissioning process with particular focus on strategies and criteria for capturing performance-based metrics. Cost-implications, benefits and roles of different agents are discussed. Transfer of qualitative goals to implementation strategies and subsequently to performance metrics is presented as a methodology for capturing design intent. Multiple qualitative goals can be expressed for energy efficiency, environmental impact and overall functionality. Implementation strategies can be developed from qualitative goals, addressing specific areas of design. Performance metrics, expressed in quantitative manner, can be utilized to set objectives for predicting, testing, measuring, verifying and monitoring performance across the building's lifecycle.

REFERENCES

[1] Turkaslan-Bulbul, M. T. and Akin, O., (2006). "Computational Support for Building Evaluation: Embedded Commissioning Model", Automation in Construction, Vol. 15, No. 4, pp. 438-447.

[2] Omer, A. M., (2008). "Energy, Environment and Sustainable Development", Renewable and Sustainable Energy Reviews, Vol. 12, No. 9, pp. 2265-2300.

[3] Perez-Lombard, L., Ortiz, J. and Pout, C., (2008). "A Review on Buildings Energy Consumption Information", Energy and Buildings, Vol. 40, No. 2, pp. 394-398.

[4] Roth, K., Westphalen, D. and Brodrick, J., (2008). "Ongoing Commissioning", ASHRAE Journal, Vol. 50, No. 3, pp. 66-71.

[5] Tseng. P. C., (2005). "Commissioning Sustainable Buildings", ASHRAE Journal, Vol. 47, No. 9, pp. S20-S24.

[6] Mills, E., Friedman, H., Powell, T., Bourassa, N., Claridge, D., Haasl, T. and Piette, M. A., (2004). The Cost Effectiveness of Commercial Building Commissioning, LBNL—56637 Report, Retrieved on 1/16/2009 from http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html.

[7] ASHRAE, (2007). Guideline 1.1-2007: The HVAC Commissioning Process, Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[8] ASHRAE, (2005). Guideline 0-2005: The Commissioning Process, Atlanta, GA: American Society of Heating, Refrigerating, and Air Conditioning Engineers.

[9] Deru, M. and Torcellini, P., (2005). Performance Metrics Research Project—Final Report, Technical Report NREL/TP-550-38700, National Renewable Energy Laboratory.

[10] Djuric, N. and Novakovic, V., (2009). "Review of Possibilities and Necessities for Building Lifetime Commissioning", Renewable and Sustainable Energy Reviews, Vol. 13, No. 486-492.

[11] Lawrence Berkeley National Lab, Design Intent Tool, Retrieved on 2/13/2009 from http://ateam.lbl.gov/DesignIntent/home.html.

[12] California Commissioning Collaborative. Retrieved on 3/3/2009 from http://www.cacx.org/index.html.

[13] NIBS Guidelines 3-2006: Exterior Closure Technical Requirements for the Commissioning Process, National Institute of Building Sciences.

[14] Energy Design Resources. Commissioning Assistant. Retrieved on 3/3/2009 from http://www.energydesignresources.com/Resources/SoftwareTools/CommissioningAssistant.aspx.

02.
HEALTHCARE THINK TANK: A COLLABORATIVE APPROACH TO INNOVATION

Kalpana Kuttaiah, Assoc. AIA, LEED® AP, *kalpana.kuttaiah@perkinswill.com*
Jim Bynum, AIA, LEED® AP, *jim.bynum@perkinswill.com*
Robin Guenther, FAIA, LEED® AP, *robin.guenther@perkinswill.com*

OVERVIEW

Our healthcare market sector is large and widespread across the firm. If there was a way to quantify the experience and expertise we have between our offices, it would be a very significant and impressive figure. Over the years we have demonstrated to ourselves the strength in our "collective collaboration" between our offices and have found ways to be innovative, creative and strategic with our collective knowledge and resources.

This article will outline the approach and intent between our firmwide "think tank" meetings – our Healthcare Center of Excellence (COE). We have brought together healthcare leadership and staff on an annual basis for a number of years for the purpose of sharing and integrating best practice ideas throughout our national and global healthcare practice. These meetings have traditionally focused on current work in each of our offices. By definition, the focus on the work has to some degree been retrospective, in that all work is a current or past client and work shared is already planned, designed and/or constructed.

For the past few years, the healthcare leadership across all offices opted to take a more forward thinking approach in an attempt to drive and define innovation.

1.0 OBJECTIVE

The COE meeting rotates each year to one of our many offices across the country. Healthcare planners, programmers, designers and healthcare practitioners on staff participate in these meetings. All of our offices are represented in this intense dialogue focused on research, innovation and technological advances in healthcare planning and design. Experts in the field of healthcare, distinguished providers, allied discipline specialists and our clients are invited to participate in a charrette* focused in generating raw, but innovative planning and design concepts. The meeting enables us to share and leverage our global expertise through a cross-fertilization of ideas and concepts among all participants from project-based experiences through working day-to-day with many of the most respected and "cutting-edge" providers across the country and around the world.

**Charrette is a term, familiar to architects, for a work session, in which participants can brainstorm solutions to a specific problem within a set period of time. It is one of the advantages of our training – we are taught to think as individuals - with highly valued differing opinions - and to present unique solutions. In school, it is more of a solitary process. In the professional arena, it is more of a collaborative process.*

Figure 1: Collaborative Charrette Process.

2.0 THE COLLABORATIVE CHARRETTE PROCESS

The elements of this process are very basic:

1. Get the right people in the same room at the same time.
2. Clearly define what you are trying to accomplish.
3. Frame the right questions.
4. Establish a time limit.

The secret to success is fostering a democratic team environment with respect for equal voices. To balance that democratic environment there also has to be a team commitment to work to a solution. This commitment ensures that decisions are made in a timely manner. Like all design challenges, the teams must triage the largest questions first and work toward the smaller details.

Since we organize our charrettes based upon collaboration, we take a large group of strong individuals, leaders in the healthcare practice, valued for their unique points of view and organize them into teams focused on the topic at hand. We include clients as guest speakers, participants and jurors for our solutions.

At first we thought it was an enormous risk to include clients in what could have appeared to be a process that was too loose, unpredictable and freeform. What we learned was that our clients were energized by the process. They were excited about working with us in a more informal way. They appreciated the importance of looking at specific design issues more broadly in the initial stages. They also appreciated looking at design and planning problems in a new way in the hope that it would offer innovative solutions as opposed to defaulting to well-known and 'safe' solutions. The collaborative team approach is essential to the success of the charrette because differing opinions, strengths and skill-sets make for better overall solutions. In that environment ideas are born, challenged, tested and refined or discarded quickly and efficiently.

3.0 STRUCTURE

As a part of these meetings we have a representative mix of all professional backgrounds ranging from architects, interior designers and planners to medical practitioners and administrators. Teams are formed prior to the charrette, deliberately distributing skill-sets as equitably as possible among teams. In addition, we pay close attention to blending the different offices on each team. Team leaders are assigned to each team and serve as an intellectual traffic cop with the responsibility of directing the discussion and work effort productively and ensuring that all work done by their groups are well documented for future reference. The shared values of wanting to do well, not wanting to look bad and the inherent competition between groups foster an effective environment for decision-making.

For these COE meetings there is a second, perhaps more important, benefit. The team building across offices is invaluable. What we have learned is that offices do not collaborate with other offices. People collaborate with people. This venue gives us the opportunity to get to know the other leaders in the healthcare practice on a personal and professional level very quickly. It essentially built the foundation for new collaboration opportunities in any region of the country. It requires knowing that someone in another office has a valuable skill. It requires knowing and trusting that person.

Outlined below are a few highlights of the past three Center of Excellence meetings conducted by our healthcare market sector and some outcomes that have helped inform our work.

4.0 INPATIENT ROOM DESIGN

For this COE meeting we chose to pursue an Evidence-Based Design Initiative focused on inpatient room design. The first step was to bring leaders in the national healthcare practice and our clients to participate in a two-day design charrette focused on three inpatient room types. Their presentations on translational design, guiding principles for patient-centric care, integration of clinical operations in the planning process, lean design for healthcare and evidence-based design helped inform the intent of the meetings. The decision to focus on this topic for discussion was the result of the convergence of: the pertinence to our healthcare clients, the timeliness of the topic, the current hospital building boom and the importance of evidence-based design. The goal was to brainstorm solutions for these room types that best showcased innovative ideas with the hope of implementing new ideas in practice. To create the appropriate environment for innovation, the charrette teams were not expected to be bound by current codes, cost concerns or square footage requirements. The only boundary set was that each team was expected to defend their solution.

4.1 Approach

We organized ourselves into six teams with two teams assigned to each room type. This approach yielded two solutions for each room type. A seventh group studied inpatient unit configurations. Readings and some baseline information pertinent to inpatient room design were provided to each team. Summary information was provided to each team concerning: a. key issues, b. design considerations, c. federal guidelines, d. typical medical equipment and e. typical staff activities. Our thought behind distributing baseline information was for it to serve as of a quick reference guide if needed. We also provided an outline of issues/variables to address in each solution including: flexibility, standardization, patient safety, sustainability and healing environments.

Our goal was to get creative solutions for the best acute care room, the best critical care room and the best acuity-adaptable room. To focus on different room types was intentional…how similar will solutions for different room types look? We wanted to consider room design from the patient perspective, staff perspective and family perspective.

4.2 Key Questions We Asked

1. One of the key challenges for the teams was to make design choices from a multitude of competing design variables and operational variables such as visibility of the patient versus patient privacy or room flexibility versus room specialization.
2. Does a single-handed room configuration also function effectively as a critical care room or an acuity-adaptable room?
3. Is there an ideal geometry for a critical care room? Is the ideal geometry compromised in implementing an acuity-adaptable room?
4. What procedures are appropriate in a critical care setting? How do those procedures affect the room design?
5. How can family members rooming-in be handled most effectively? Murphy bed? Fixed built-in day bed? Recliner?
6. Should private rooms be built to semi-private standards for future flexibility? Is there any scenario by which a private room would need to swing to become a semi-private (even temporarily) in the future?
7. Are there advantages to one toilet configuration over others: a. Inboard, b. outboard, c. midboard, d. nested?
8. Is a single-handed room a preferred model over the mirror-image room model?
9. Do nested rooms work as effectively as critical care rooms?

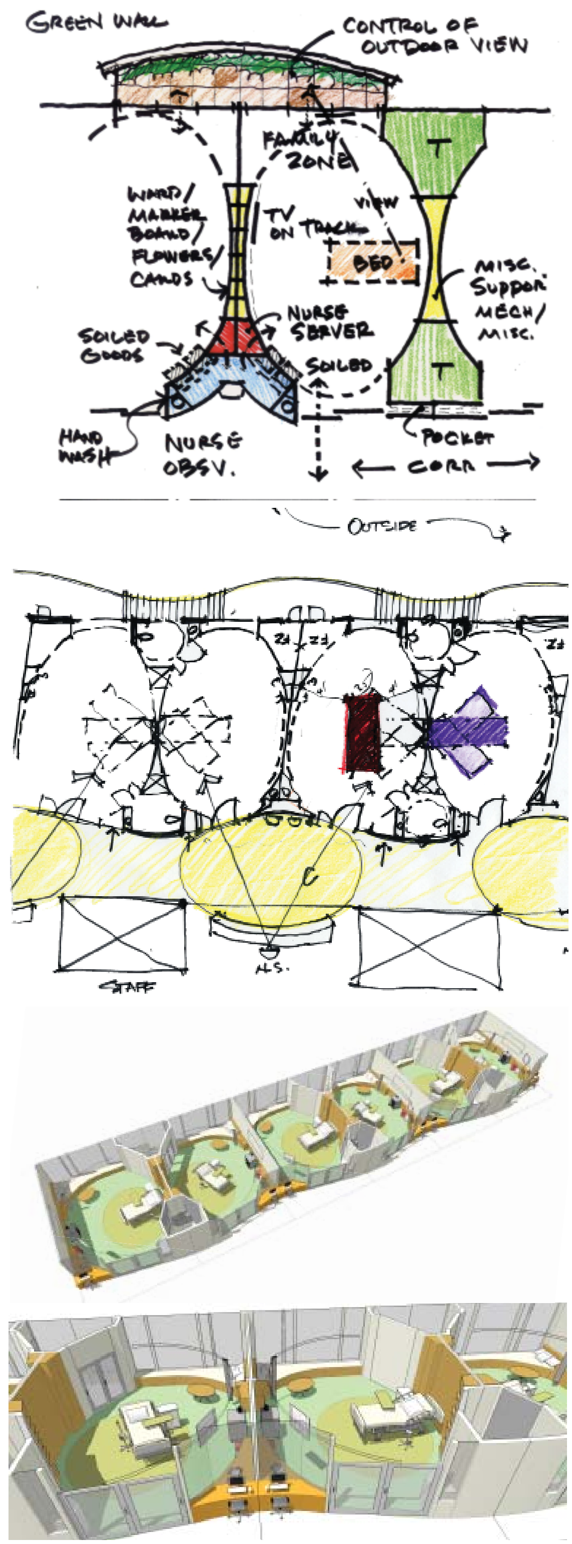
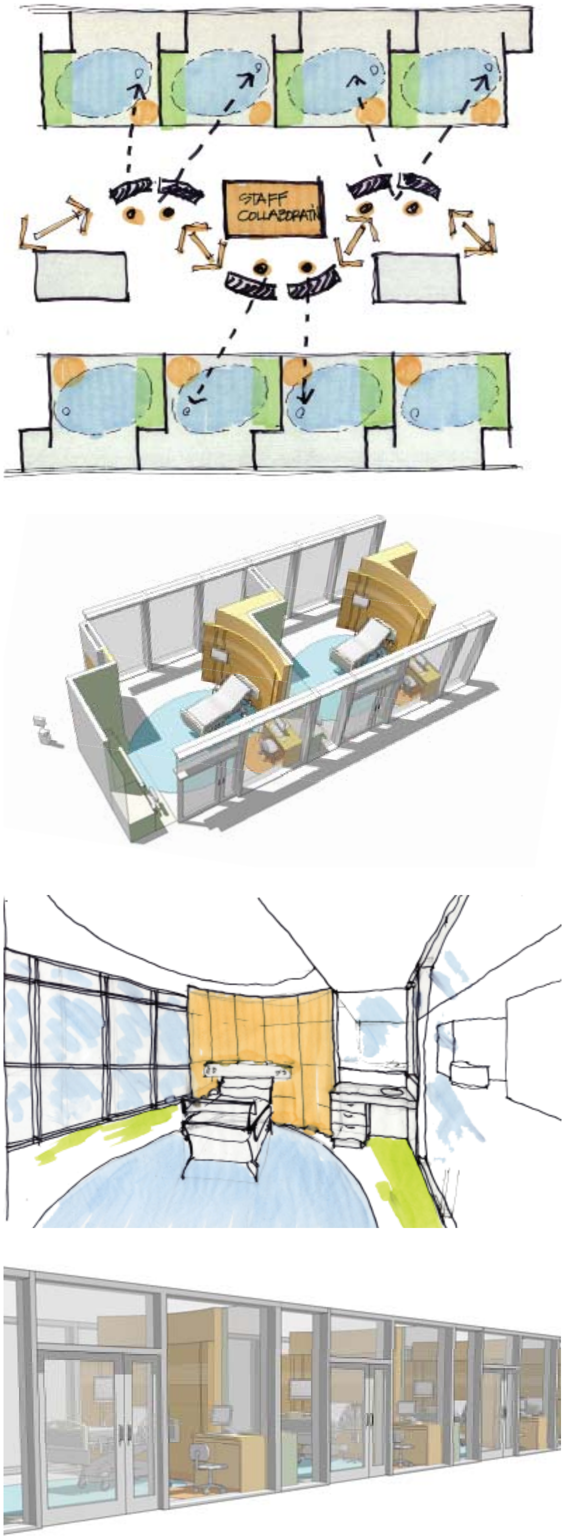


Figure 2: The concept for their iteration of the acuity-adaptable patient room stemmed from the maximum flexibility of the patient environment addressed by the bed position and staff interaction. The oval shape was derived by taking the "Patient Halo." With the use of an overhead boom, the ability to position the patient bed in any of 360-degree axis points would provide the greatest amount of flexibility, which in turn could address the need to deliver care for any acuity level of the patient.



4.3 Findings

Our charrette persuaded us that there is not one proto-typical patient room that satisfies all patient requirements. We would be skeptical of anyone claiming that “one size fits all”. Operational issues are the overwhelming space drivers of our day. As healthcare architects, we seek to create space that supports a healing environment for the patient, supports the needs of the patient’s family and supports clinical functions for staff and physicians.

- We determined that single-handed rooms can serve as effectively as acute care, stepdown or critical care rooms, but may be best suited for acute care rooms.
- Larger rooms are better for future flexibility. Private patient rooms could be sized to flex to semi-private rooms (temporarily) in the future to accommodate sudden increases in patient volumes due to catastrophic events.
- The majority of solutions provided more family space than is traditionally planned. The consensus was that family will not only continue to room-in with patients and act as patient advocates, but may even have an expanded role in the future.
- Daylighting should be brought into bathrooms via clerestory windows.
- Patient room design should be treated as a six-sided room with attention to floor and ceiling surfaces.
- A higher degree of transparency in the corridor partition separating patients from staff may be appropriate for acute care rooms.
- Inpatient rooms should be planned as universal rooms – sized and configured to serve as acute care rooms or with modifications as critical care rooms – over the lifecycle of the building.

All those who participated felt enriched by the experience. It helped remind us how best to engage our clients – in an open, honest, interactive dialogue – while setting aside preconceptions. We need to continue to pursue opportunities to incorporate the collaborative charrette approach into our work process with our clients.

Figure 3: Conceptual views for a critical care room attempting to provide a total care environment by demarcating zones for the patient, family and staff by integrating all three to allow for the best delivery of care for the patient.

5.0 FUTURE HEALTHCARE SCENARIOS

For this COE meeting the topic - "How Will Healthcare Delivery Look 50 Years from Now?" – was selected to take us out of our comfort zone. The topic reaches beyond our careers and beyond many of our life spans. Just as in master planning, we look to a longer horizon (20 years) for an understanding of the general direction of things, to better inform near-term decisions (0-10 years); we chose a broader topic to better inform the planning we are doing today. Technology was central to our focus on the future. It is not too early to begin thinking about and planning for the revolutionary technological change we will see in our lifetime.

To get a better handle on a 50-year horizon, we created a timeline of healthcare and technological innovations over the last 50 years. This timeline served as a point of departure for our dialogue about the future, with the understanding that technological innovations will occur more rapidly over the next five decades than they did in the last five. Also of interest, were some "non-starter" technologies represented in the timeline.

Our challenge was to identify the key drivers impacting the future of healthcare. We also considered many other criteria such as financial, climactic, geographic and cultural influences in envisioning our scenarios of the future. Like any exploration of history, which is a fragmented account by definition, our future scenarios most clearly revealed fragments of consensus about the future.

The presentations delivered by our guest speakers covered the topics of the technology driven revolution in healthcare, vision of future healthcare, building for tomorrow's market and pulsating with knowledge- the "hospital" for the future. The diversity of our guest speaker presentations and their in-depth knowledge in their field of expertise helped inspire the group discussions that followed. Our speakers were also participants in the charrette process over the following two days. They also made up the panel on the last day of the meetings when each of the groups had to present their scenarios.

5.1 Approach

Our process was like a kind of virtual sonar. We planned for scenarios in healthcare delivery (50 years out) to inform our more immediate planning and design over the next two decades (master planning horizon).

Two pairs of teams worked together to identify the key drivers that would impact the healthcare delivery most over the next 50 years. They had to define and explain the impact of these key drivers, and identify the technology drivers they thought would shape healthcare delivery the most, and explain their impact. The teams then worked separately to create scenarios for the future - what they thought healthcare delivery would look like 50 years from today. The groups had to describe the implications of their scenario to near-term healthcare planning and design and define what would be the healthcare planning and design opportunities and innovations over the next 10-20 years.

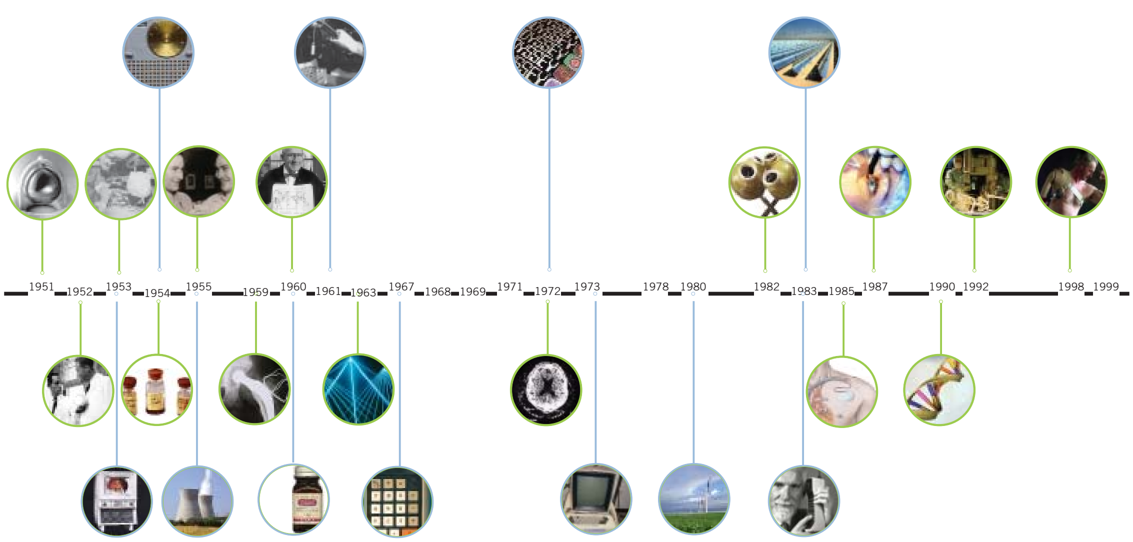


Figure 4: Section of the timeline done on medical inventions.

5.2 Key Questions We Asked

Two generations hence and a decade after the last of the baby-boomers have retired, how will healthcare delivery be structured in the United States? What will be the *key factors* that will precipitate change?

1. Will hospitals still exist? What will be the average human life-span? What impact will life-span have on healthcare delivery?
2. What role will converging technologies play in average human life-span? What role will technology play in changing healthcare delivery?
3. What will be the make-up of care teams? Will nurses be part of the care team? What role will they play? Will care teams work in an inpatient, outpatient, home-care or virtual setting?
4. Will healthcare delivery still be competitive in nature? Will Nationalized Medicine be implemented? Will genomic mapping impact how care will be offered or funded?
5. What impact will an aging population in the U.S. have upon healthcare delivery? What population changes will have occurred that might impact care delivery?
6. Will healthcare delivery be centralized or decentralized? What services will be accomplished at home?
7. Will climate changes impact the workforce? Will climate impact geographic distribution or redistribution of population in the U.S.?

5.3 Findings

Our charrette made us aware that we are in the earliest stages of a new era which may be defined as the Bio-information Age. The Bio-information Age will be characterized and aided by new technology internal to the human body. This new era would apply existing and new technologies that would greatly impact and help advance current patient care models.

- Full body scans with 3D (structural) and 4D (functional) imagery will become the predominant patient data record in the future. It will be used to monitor disease processes and treatment outcomes.
- The next major wave of productivity will occur through devices and technology internal to the human body.
- Approximately 30-40% of patients receiving inpatient stays in the hospital by today's standards will be in some form of monitored home care in the future.
- The most likely scenario for a universal patient record is that it will emerge though existing information structures such as Google or My Space and will be driven by consumer (patient) participation.
- Gene mapping will play a role in how healthcare is funded in the future.
- Disruptive technologies will change how and where healthcare is delivered.
- Available technologies and accessible technologies are different things. The wealthy will purchase technology in the future to improve function and to extend lifespan.
- Medical ethics will be sorely challenged in the future.

6.0 VALUING GREEN: DEVELOPING A FRAMEWORK FOR SUSTAINABLE HEALTHCARE

In 2007, Perkins+Will became the first firm to commit to the goals of the AIA 2030 Challenge – a commitment to reduce greenhouse gas emissions to zero in all new buildings by 2030. Since 2003, the imperative to act swiftly and decisively on delivering quality buildings while reducing climate change impacts and supporting the transformation of the materials marketplace to safer, healthier alternatives has become a core business principle of Perkins+Will.

For the healthcare sector, partnering with our clients to protect the health and safety of building occupants, their communities and the broader global community has emerged as a key tenet of our practice. The topic – "Valuing Green: Developing a Framework for Sustainable Healthcare" – was selected to link together the key objectives of sustainable design with the core values of the healthcare sector for whom we deliver services.

We believe that more than any other single influence in the design and construction industry, sustainable design is positioned to radically alter the landscape of healthcare infrastructure development in the early decades of the 21st century. Around us, healthcare clients and our practitioners who serve them are seeking frameworks and resources to measure as well as manage the emerging strategies, technologies and methodologies that will transform the production and operation of the built environment.

This program was intended to provide a set of tools and lenses for us to assist our healthcare clients in delivering 21st century buildings that will continue to serve them well in the tumultuous decades before us.

We had presentations delivered by our guest speakers that covered the following topics: 1. Doing more with less: rethinking for sustainability; 2. Green into gold: restoration economy and urban landscape health; 3. Evaluation of the energy issues for an emerging best practice hospital, Green value: the sustainable business case and 4. Building environmental performance: assessing progress. Once again, our speakers were also participants in the charrette exercises over the following two days. A few of them also made up the panel on the last day of the meetings when each of the groups had to present their scenarios.

We set out to formulate a new and compelling answer to the question: “How do we handle sustainable design at Perkins+Will?” Using materials gathered from frameworks ranging from LEED® to the Living Building Challenge, we attempted to:

- define a new baseline for the design of healthcare facilities that recognizes the broader Sustainable Design Initiative (SDI) goals
- develop a sustainable design framework to continuously review and refine our healthcare projects - one that directly links to the mission and vision of our clients and our larger practice goals
- catalog strategies for achieving carbon-neutral, toxic-free, zero-waste, water balanced and inspirational-hospitals
- create a research agenda for the future aimed at overcoming the challenges and obstacles to achieving this vision of excellence

6.1 Approach

Through design excellence, we hoped to go from today’s standard practice of designing for sustainable healthcare facilities, to creating regenerative healthcare buildings in the future. Our approach was to define a series of tiers of accomplishment of sustainable design. Beginning at the bottom as Tier 1, would be what is considered current standard practice in hospital building (in the case of new construction). In the case of renovation/interiors, we can broadly define the base as a client with no sustainable design objectives in their interiors standards or commitment to sustainable design. The tiers graduate in accomplishment up to Tier 4, to a goal of a Living or Regenerative building, with major characteristics of each outlined.

We organized ourselves into 12 groups for the first exercise. We co-created a wall chart to help us measure and manage the transformation of our practice around sustainable goals and vision. We then reassembled into six groups, based on broad categories of client goals and the wall chart created in first exercise and strategized how we would achieve undertaking building sustainable healthcare projects.

6.2 Key Questions We Asked

The design of the built environment has a profound impact on achieving excellence in these arenas and sustainable design offers a powerful set of strategies and tools for 21st century healthcare.

1. Can we define a framework for sustainable design thinking that responds to the unique challenges of the healthcare built environment and the values of our clients?
2. Can we co-create tools that will help us measure and manage the transformation of our practice around sustainable goals and vision?
3. Can we transform the design of healthcare environments using sustainable design thinking to deliver VALUE to our clients through improved safety, quality and health? Culture?
4. What drives the adoption of sustainable design principles in healthcare settings?
5. What are we, as designers, seeking as we begin to integrate sustainable design principles in our projects?
6. What are the measures of excellence in 21st century healthcare design?
7. What do our clients VALUE?

6.3 Findings

Regenerative and Living Building hospitals are more than the sum of points achieved on a LEED checklist. They represent a fundamental shift in the way we view hospitals within the fabric of our cities and our lives. Twentieth century hospital design has its basis in the curative model of disease – that is, one in which the hospital isolates itself from its community in order to “cure” the patient. As we discovered in this COE, sustainable design offers us the framework and tools to move toward healthcare design that recognizes that chronic disease and health management now define our 21st century hospital infrastructure and that hospitals must become vital and engaged community participants. As one reads across the Tier 4 strategies in the wall chart, the strategies suggest a healthcare infrastructure that shares the properties of nature (resilient, renewable, regenerative) rather than existing in opposition to it.

The framework developed here is an initial tool to guide our practice and our clients in transforming the built environment toward this vision. Collectively, we have defined a new ‘sustainable baseline’ for healthcare projects – both new construction and interiors. The challenges that were identified begin to define a research agenda for the healthcare market sector in the coming years. The new working relationships that we forged with one another in this meeting of discovery and growth will serve our clients well in future work.

Finally, this exploration in sustainable design reveals that achieving sustainable design goals is inextricably linked to the broader pursuit of design excellence and integrative design. It challenges us to redefine the silos of traditional disciplines of architecture, medical planning, landscape, site and systems in the pursuit of interdependent, integrated design solutions. This framework can be an important tool in assisting us to achieve new levels of integrated thinking in our work.

Through the consideration of Living and Regenerative Buildings, we can assist our clients in leapfrogging beyond LEED and create a vision of a fundamentally transformed built environment for healthcare to inform the buildings we design today. Even where it is not possible to fully achieve Living Buildings today, situating hospitals in the broader ecology of a community is a compelling and necessary vision for their long-term life and adaptability. Perkins+Will, as a leading healthcare design firm, has an important role to play in leading and modeling this transformation.

6.4 Next Steps

Following the last COE meeting there were a series of structured workshops in evolving this vision and the tools that accompany it through the Perkins+Will healthcare practice. Each region hosted a Regional COE to further develop the vision of Regenerative and Living Buildings in healthcare projects and refine the wall chart tools. These regional COE's focused on the unique aspects of each bio-region as well as particular market drivers.

The wall charts developed at the main meeting were refined through the regional meetings. Each Regional COE introduced the wall chart and LEED-registered healthcare projects. Teams were asked to fill out a wall chart with the strategies they are pursuing outlined in order to gain a greater sense of the viability of the defined baseline and the strategies they are achieving.

7.0 SUMMARY

As part of the exercise, in the last COE, each group was asked to uncover significant roadblocks while placing their strategies in the tiers of accomplishment – annotating it with the name/issue that defines the roadblock. We will be conducting further research into these issues. The "challenge area" identified by the icebergs in the wall chart exercise have now evolved into individual research topics. These topics will form the basis of white papers, design exercises or firmwide webinars with the expressed intent of providing resources to assist teams in overcoming these barriers to improved sustainable building performance.

The healthcare market sector's COE initiatives have helped us position our research and best practices, which in turn informs the design of the next generation of ideas. This learning cycle furthers innovation in our approach to design and contributes to our clients' quality of healthcare delivery. Each year the tools and results from these meetings are shared through many venues. This knowledge sharing helps not just Perkins+Will, but our clients and the industry as well as it influences our work and equips us to be leaders in the healthcare design practice.

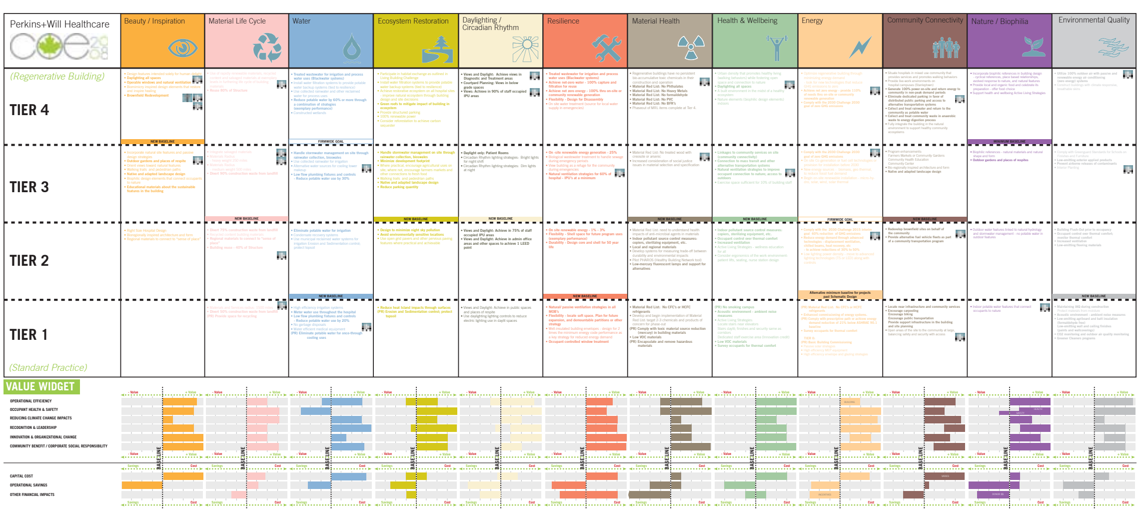


Figure 5: Wallchart of Strategies.

03.

CHOOSING THE RIGHT GREEN BUILDING RATING SYSTEM

An Analysis of Six Rating Systems and How They Measure Energy

Michael Driedger, BA Dipl.T., LEED® AP, *michael.driedger@busbyperkinswill.ca*

ABSTRACT

This paper is based on a technical report that was intended to provide the University of British Columbia's (UBC) Sustainability Office with a potential strategy to move the Point Grey Campus to carbon neutrality without the purchase of carbon offsets by 2030 and to recommend a green building rating system that would form part of this strategy. The paper will focus on the analysis of the following green building rating systems and how they measure energy and carbon.

- BOMA Go Green (Canada and the US)
- BREEAM (UK)
- Green Star (Australia)
- Passive House (Germany and the US)
- The Living Building Challenge (Canada and the US)
- LEED® (Canada and the US)

The paper will look at available rating systems for new and existing buildings, but will not cover single family residential rating systems.

KEYWORDS: Green Building, Rating Systems, Carbon, Energy

1.0 INTRODUCTION

The Architecture 2030 Challenge, along with the USGBC and CaGBC's adoption of a more stringent energy standard for LEED, demonstrates an increasing focus on energy efficiency. This is nothing new to the green building industry; however the increasing emphasis on energy's carbon emissions is indicative of our urgency to address climate change.

It is not uncommon for a client to ask, "Which green building rating system standard will result in the greatest reduction on our carbon footprint?" While this is a very legitimate question there are very few straightforward answers. The Architecture 2030 Challenge was meant to address the lack of clarity in the industry however the need for building ratings remains.

This report is based on the UBC Sustainability Office's commissioning of a report by Busby Perkins+Will to help answer one question:

- What green building rating system for new and existing construction would be most appropriate to UBC's Point Grey campus, given the University's goals for greenhouse gas emission reductions?

The report looked at: BOMA Go Green, BREEAM, Green Star, Passive House, The Living Building Challenge and LEED.

2.0 PAPER METHODOLOGY

Given the objective of this study, this section provides clarity regarding the terminology used pertaining to greenhouse gas emissions and criteria used to rank and evaluate the green building ratings systems.

Any general references to GHG, GHG emissions or carbon within this document refer to a gross emissions estimate, for six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Therefore, the common terms of GHG, GHG emissions, carbon and CO_2 are more specifically in reference to CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas to global average radiative forcing on a 100-year Global Warming Potential (GWP)1.

The majority of clients are interested in green building rating systems that could help them meet GHG reduction targets. This report therefore, outlines only those ratings systems that are applicable to a North American climatic zone and are available in English. The following criteria have been developed for evaluating and prioritizing green building rating systems:

- *Criteria #1: Effectiveness at reducing CO2 emissions.* Effectiveness is measured by the rating system's rigour regarding energy reduction and therefore, CO2e reductions, as well as the rating system's ability to accurately measure CO2e. This criterion has been multiplied by a factor of two in order to reflect the importance of CO2 reductions. Both LEED and Green Globes have been analyzed as though 5 (LEED) and 50 (Green Globes) energy credits were the energy minimums. The importance of a rating system's effectiveness at accurately measuring and reducing GHG emissions is therefore the most important criteria. To demonstrate this, all scores are multiplied by a factor of 2.
- *Criteria #2: Cost of certification.* This includes the cost of registration and certification and does not include soft costs associated with documentation and energy modeling. Costs can range from no cost to very expensive (relative to no cost self assessments) as defined in the table below.
- *Criteria #3: Market adoption and ease of use in its country of origin.* This refers the capacity on the part of the provider to respond to user needs in the marketplace. "Ease of use" is defined as the amount of documentation required for certification under the rating system. Criterion 3 is further defined in the table below.

Table 1: Rating system ranking criteria.

SCORE	CRITERIA #1 Effectiveness at reducing CO2	CRITERIA #2 Cost of Certification	CRITERIA #3 Adoption and ease of use in North America
0	Does not address the criteria.	Very Expensive >$10,000	No North American market adoption unable to respond to user needs
1	Addresses the criteria by prompting action but without measuring carbon or setting an energy minimum	Expensive $5,000 - $10,000	Some North American market adoption and able to respond to user needs
2	Somewhat addresses the criteria, but does not have effective tools for measuring CO2	Moderate cost $2,000 - $5,000	Good North American market adoption and the provider plans to respond to user needs
3	Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement and raise the energy minimum.	Low cost $1 - $2,000	Strong North American market adoption and the provider responds to user needs
4	Fully addresses the criteria of reducing carbon	No Cost $0	Best North American market adoption and the provider actively responds to user needs

3.0 ANALYSIS OF RATING SYSTEMS, CHALLENGES, AND CODES

An analysis of various green building rating systems, challenges and energy codes is outlined in section 3. A summary and recommendation of the most appropriate rating system is presented in section 4 of this paper.

3.1 Green Building Rating Systems

A summary of the following green building rating systems is provided in this section: the LEED Green Building Rating System, Green Globes, BOMA Go Green and Go Green Plus, BREEAM, Passive House, Green Star and the Living Building Challenge. For each rating system a description of the energy standard, certification procedure and estimated cost of certification is provided.

3.1.1 Leadership in Energy and Environmental Design (LEED) Summary

The Canada Green Building Council (CaGBC) and United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Green Building Rating System is a voluntary and consensus

based rating system used by a diversity of market sectors in Canada and the United States as the certification Benchmark for high performance green buildings.
LEED is a system made up of prerequisites and credits. All prerequisites must be achieved in order to seek LEED certification. If a project can not meet a prerequisite, then the project can not seek certification with either the USGBC or CaGBC. The system is divided into 5 environmental categories and a sixth category for Innovation and Design:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation and Design

Achieving a certain number of credits will determine what level of certification a project will receive. There are four levels of certification:

- Certified
- Silver
- Gold
- Platinum

The difference between registration and certification is an important distinction. A "Certified" building is one that has gone through the rigorous process of third party assessment upon completion of the project. Whereas a registered project is one that is under design and will most likely pursue final certification upon occupancy.

There are a number of LEED "products" available in the marketplace including, but not limited to:

- LEED NC (for New Construction & Major Renovation projects), available in Canada
- LEED EB (for Existing Building minor renovations and operational efficiencies), available in Canada in 2009
- LEED CI (for Commercial Interiors or other tenant improvements), available in Canada
- LEED CS (for Core and Shell developments for developer driven projects), available in Canada

There are also two new rating systems, LEED for Homes (H), and LEED for Neighbourhood development (ND), which will not be discussed in this paper.

The Canada Green Building Council will be rolling out LEED 2009, the next iteration of LEED for the Canadian market place in the fall of 2009. LEED Canada 2009 will closely parallel LEED 2009 by the USGBC and it will assess projects based on the new 110 point scorecard.

To further emphasize the role that buildings play on the environment, the USGBC has mandated that all LEED for New Construction 2.2 and Core and Shell 2.0 buildings must achieve the first two energy and atmosphere credits and will automatically (at no cost) be registered for LEED for Existing Buildings. This increased energy requirement will result in a minimum energy reduction of 20% for all new projects. This requirement has not yet been adopted by the CaGBC, but will appear when the CaGBC launches LEED 2009.

LEED for New Construction

LEED NC 1.0 was the first product released by the USGBC and CaGBC. LEED NC is designed to assess the performance of new or major renovations of largely owner occupied buildings, such as commercial and institutional buildings.

Since we are interested specifically in how effective a rating system is at reducing GHG emissions, the analysis in Table 2 was prepared to assess the energy performance of 5 energy credits for 7 LEED projects in BC. It compares the energy intensity for a building that is 35% better than ASHRAE 90.1-1999 (i.e., 5 LEED Energy credits); however White Rock Operations Facility and Dockside Green Synergy were left as they were modeled to give a sense of the energy intensity ranges associated with percentage energy reductions. A column has also been added for heating energy intensity in order to assess the feasibility of using the Passive House Standard (see Section 3.1.5).

The New Buildings Institute released a study of 121 LEED NC buildings in March of 2008, that outlined the average energy intensity of buildings built to varying LEED certification levels. The study, completed for the USGBC, revealed that the average energy intensity for LEED Gold buildings was 161 kwh/m²/yr. This analysis did not account for the number of energy credits pursued or the building type. Rather, this data included projects that achieved between 0 to 10 energy credits, buildings from Arizona to Alaska and lab buildings to largely empty warehouses. The study largely surveyed: interpretive centres, K-12 schools, libraries, mixed-use buildings, multi-unit residential buildings, office buildings, municipal buildings, lab buildings and a range of miscellaneous buildings.

As the data in Table 2 will testify, it is difficult to conclude average energy intensity for an energy standard that is meant to be relative to a reference building in a specific climate.

Table 2: Comparative modeled energy performance for LEED New Construction Buildings[7].

Building Name; Location, Energy Credits	Total Energy Intensity (kWh/m²/yr)	Heating Energy Intensity (kWh/m2/yr)	Building Type	Source	Location
Computer Sciences Building University of Victoria based on 5 credits	130	3 - Electric	Office, Class, Lecture	CaGBC Letter Templates	Victoria, BC
Vento based on 5 credits	197	97.8 - Natural Gas	Multi-unit Residential	CaGBC Letter Templates	Calgary, AB
Aquatic Ecosystems Resource Lab (UBC) based on 5 credits	123	71 - Natural Gas (Steam)	Lab, Class, Lecture	CaGBC Letter Templates	Victoria, BC
Life Sciences Building (UBC) based on 5 credits	1,378	667 - Natural Gas (Steam)	Lab	CaGBC Letter Templates	Victoria, BC
White Rock Operation Facility based on 8 credits	81	17 - Mixed	Office	CaGBC Letter Templates	White Rock, BC
Dockside Green Synergy based on 10 credits	98	3 – Biomass	Multi-unit Residential	CaGBC Letter Templates	Victoria, BC
Average Gold Building energy credits vary	160	Data not available	All types from lab to empty warehouses	New Buildings Institute Study 2008	Throughout the U.S.

LEED for Existing Buildings

LEED EB-O&M (Operations and Maintenance) is one of the newest rating systems developed by the USGBC. The documentation is designed to be completed by operations and maintenance staff and focuses on actual building performance data and improvements. Currently only buildings in which 75% of the spaces meet the standard can be certified under this rating system. This eliminates a single floor in a building from achieving LEED EB-O&M certification. For a building to retain its LEED certification status it must re-register and certify under LEED EB-O&M every 5 years. The intention is to ensure that a building is performing as designed and for improvements to be made during the operational stage of the building. LEED EB-O&M is currently being reviewed and adapted by the CaGBC and will be launched in summer of 2009.

The most applicable credits to this paper pertain to the Energy and Atmosphere section. This rating system is the only system that awards a project for reporting GHG emissions through formal participation in a third-party voluntary reporting or certification program. There is also the option of using a calculation methodology of a technically sound third party voluntary reporting or certification protocol with a performance period between three months and 2 years.

There are 4 credits for building energy and water metering that address load patterns and occupant behavior. For example, LEED EB-O&M requires that a building measure one water source for each water credit (i.e., intake water for 1 credit and the addition of heated water for a second credit). Similarly, it requires that a building separate at least one energy load (such as lighting) for 1 credit and at least 2 loads (e.g., lighting and plug loads) for 2 credits. The advantage of measuring specific loads in existing buildings is that it enables operations staff to implement more effective building energy efficiency measures based on actual occupant use patterns.

The following table outlines the various LEED products and relevant energy code or standard it references.

Table 3: LEED product and applicable energy standard.

PRODUCT	ENERGY STANDARD
LEED NC Canada 1.0	ASHRAE 90.1 1999 and the MNECB
LEED NC USGBC 2.2	ASHRAE 90.1 2004
LEED EB for Operations and Maintenance	Energy Star
LEED CI Canada	ASHRAE 90.1 2004 E-Benchmark Commercial Building Incentive Program
LEED CI US	ASHRAE 90.1 E-Benchmark
LEED CS	ASHRAE 90.1 2004
LEED H US	Energy Star using Home Energy Rating System (HERS)
LEED H Canada	EnerGuide and HERS

LEED Summary Energy Summary

While the new LEED EB for Operations and Maintenance is the only LEED product with a credit for carbon reporting, all other LEED products track carbon through the LEED letter template. The Canadian LEED letter template shows not only total energy reduction, but also total carbon reduced in tonnes. The GHG emissions reduction values generated within the template are based on Environment Canada's GHG emissions inventory 1990-2002 data (average intensity for Canada, which is approximately 270 tonnes CO2e/GWh)[6] with an adjustment factor to account for line losses and upstream emissions. Therefore, the GHG emissions calculation within the letter template does not accurately reflect the energy mix (of approximately 84 tonnes CO2e/GWh) used in British Columbia or any other province.

A LEED NC, CS or CI certified building in Canada can cost anywhere between $3,675 to $17,000 to register and certify based on square footage and whether a full energy review is requested. A LEED EB-O&M project (registered with the USGBC) typically costs $3,000 to $8,000 to register and certify.

Table 4: LEED summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
LEED NC, CS or CI (Canada)	ASHRAE 90.1 and MNECB	35% better than ASHRAE; 42% better than MNECB	6 points	0.5 points	3 points	9.5 points
LEED EB (U.S. and Canada in 2009)	Energy Star or EnerGuide	20% better than National Average	6 points	1.5 points	3 points	10.5 points

Table 5: LEED ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
LEED NC, CS or CI (Canada)	3 points: Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement and raise the energy minimum.	3x2= 6 points	$3,675 to $17,000 to register and certify	0.5 points: Between Expensive and Very Expensive	Strong North American market adoption and the provider responds to user needs	3 points
LEED EB (U.S. and Canada in 2009)	3 points: Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement and raise the energy minimum.	3x2= 6 points	$3,000 to $8,000 to register and certify	1.5 points: Between Moderate and Expensive	Strong North American market adoption and the provider responds to user needs	3 points

3.1.2 Green Globes

Green Globes is a system developed using the Building Research Establishment's Environmental Assessment Method (BREEAM). In 1996, the Canadian Standards Association (CSA) published BREEAM Canada for Existing Buildings. In 2000, the system became an online assessment and rating tool under the name Green Globes for Existing Buildings. In the same year, the Canadian Department of National Defense and Public Works and Government Services developed a system for the design of new buildings. The product underwent a further iteration in 2002 by a team of representatives from Arizona State University, the Athena Institute, BOMA and several federal departments including Public Works and Governments Services and Natural Resources Canada.

Projects are awarded points based on their performance in seven areas of assessment in the New Construction module and six in the Existing Building module. The checklist (or scorecard) for the New Construction module is organized by green building practices as well as the sequence of the design process. The project dashboard is divided into 6 project delivery phases:

- Pre-design Project Initiation
- Pre-design Site Analysis
- Design Development
- Construction Documents
- Contracting and Construction
- Commissioning

Each of these phases is subdivided into seven assessment areas: Project Management, Energy, Indoor Environment, Site, Water, Resources, and Emissions (similar to Indoor Environmental Quality in LEED). Projects complete an online questionnaire at the end of each stage, in addition to offering project design teams suggestions aimed at reducing the building's overall environmental impact. Green Globes has dedicated most of its points to energy performance, however there are no specific energy targets. Much like LEED EB-O&M, Green Globes uses performance benchmark criteria to evaluate the probable energy consumption of a building. The existing building module compares a building's energy performance against data generated by the EPA's Target Finder (Energy Star), which reflects real building performance. The New Construction Module uses the Canadian Model National Energy Code for modeled building comparison.

Green Globes can be used for self-assessment, but if a project team wishes to claim compliance with a specific Green Globe certification, a third-party review of the documentation is required. Official certification is obtained through the submittal of required project documentation as well as a project walk-through by regional reviewers. Projects are awarded a final rating of one (35–54 percent), two (55–69 percent), three (70–84 percent) or four (85–100 percent) globes based on cumulative point totals.

The entire rating system is based on 1000 total points with 380 points allocated to energy. The 380 points are distributed over 5 different energy credits that address: energy performance, energy demand, energy systems, renewable energy and transportation energy. The most relevant sections to this study are Credit 1 (energy performance) and Credit 3 (integration of energy efficient systems).

Credit 1 for energy performance allocates 100 points and projects must employ a design that meets the energy performance targets below:

- less than 258 kWh/m²/yr, which is 20% more efficient than MNECB
- less than 215 kWh/m²/yr, which is 25% more efficient than MNECB
- less than 194 kWh/m²/yr, which is 30% more efficient than MNECB
- less than 172 kWh/m²/yr, which is 35% more efficient than MNECB
- less than 151 kWh/m²/yr, which is 40% more efficient than MNECB
- less than 130 kWh/m²/yr, which is 45% more efficient than MNECB
- less than 108 kWh/m²/yr, which is 50% more efficient than MNECB

The Green Globe rating system has attempted to conclude an average energy intensity can be inferred from an energy standard that is meant to be relative to a reference building in a specific climate. As noted in section 4.1.1, it is very difficult to draw a parallel to energy intensity and a percentage energy reduction relative to MNECB or ASHRAE.

A 50% reduction or more is worth 100 points and a 40% reduction is worth 50 points (roughly equivalent to 5 energy credits under LEED NC). For a detailed comparison of Green Globes and LEED please see Table 6.

Credit 3 for integration of energy efficient systems is worth 66 points and requires specific energy efficient technologies, such as:

- High-efficiency lamps and luminaries with electronic ballasts
- Lighting controls
- Energy-efficient HVAC equipment.
- High efficiency or condensing type boilers or other higher-efficiency heating systems (e.g. infrared heating in industrial buildings)
- High efficiency chillers
- Energy-efficient hot water service systems
- Building automation systems
- Variable speed drives
- Energy-efficient motors on fans/pumps
- Energy-efficient elevators
- Other energy-saving systems or measures (i.e., displacement ventilation, cogeneration systems, heat recovery system, etc).

Table 6: Green Globe / LEED Energy credit comparison.

Green Globes	Green Globes Points	LEED MNECB Value	LEED Points
20%	10	24%	1
25%	20	29%	2
30%	30	33%	3
35%	40	38%	4
40%	50	42%	5
42%	60	47%	6
44%	70	51%	7
46%	80	55%	8
48%	90	60%	9
50%	10	64%	10

Most of the process is online and “third party verification” amounts to the design being assessed by a verifier. A verifier is either a licensed architect or building engineer with knowledge and experience of green building technologies and integrated design. Once the verification is complete, the project is awarded a Green Globes certificate. The verifiers under this system would not be considered third party verification under LEED as there are no rules that the verifier can not be part of the design team. There are a number of conflicts of interest inherent in the Green Globes assessment methodology and little documentation is required for an assessment of a project.

Table 7: Green Globes summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
Green Globes (New Building Module)	MNECB	None defined	4 points	3 points	2 points	9 points
Green Globes (Existing Building Module)	Energy Star	None defined	4 points	3 points	2 points	9 points

Table 8: Green Globes ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
Green Globes (New Building Module)	2 points: Some what addresses the criteria. Does not have effective tools for measuring carbon	2x2= 4 points	$250 to $500 for self assessment and verification	3 points: Low cost	Good North American market adoption and the provider plans to respond to user needs	2 points
Green Globes (Existing Building Module)	2 points: Some what addresses the criteria. Does not have effective tools for measuring carbon	2x2= 4 points	$250 to $500 for self assessment and verification	3 points: Low cost	Good North American market adoption and the provider plans to respond to user needs	2 points

A Green Globes existing or new building in Canada can cost anywhere between $250 for a self assessment and an additional $500 for a verifier to certify the building.

3.1.3 Building Owners and Managers Association (BOMA) Go Green and Go Green Plus

BOMA Go Green and Go Green Plus are voluntary programs designed for existing or occupied buildings. It is offered by BOMA Canada as a service to all member and non-member commercial building owners. It is not the intent of this program to direct building owners on how to manage their buildings, but simply to recognize those buildings where environmental best practices have been implemented into the operations.

Criteria for the BOMA Go Green program were established following consultation with the building industry. The underlying premise to the criteria development was a belief that most buildings are currently managed by professionals who have implemented, or are planning to implement, good environmental practices into daily operations.

Notable requirements for the program include an energy audit and preventative maintenance programs. An energy audit of the applicant's building must have been performed within the past three years for the building to be eligible for certification. Building management staff must also have a written plan to address energy issues raised in the audit and must have in place a heating, ventilation and air conditioning (HVAC) preventative maintenance program.

Energy audit requirements are for a 'Phase 1' audit. This is an energy inventory performance analysis with a plan that identifies energy reduction opportunities. It does not require a capital cost analysis. An energy audit may cost anywhere from $4,000 and upwards. The audit may be completed by 'in-house' technical staff provided the audit and report meet the minimum standard of practice as specified in the BOMA reference guide. There are three alternative means of compliance for the energy audit requirement, which are as follows:

- Buildings that are less than three (3) years old may provide a design energy report produced during the design of the original building.
- Buildings that have over 75% of the total energy consumption directly purchased by tenants may provide an energy communications plan that encourages conservation by tenants in lieu of an energy audit.
- Buildings that have had an energy audit performed more than three years ago, but less than five years ago, and have implemented the majority of measures recommended in the audit may provide an energy update report in lieu of a new energy audit. This report must identify which conservation measures have been implemented since the time of the original report.

A Go Green or Go Green Plus certified building can cost anywhere between $750 to $7,000 based on square footage and whether the submission comes from a BOMA member or non member.

Table 9: Go green and go green plus summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
BOMA Go Green Go Green Plus (U.S. and Canada)	Energy Audit	None defined	2 points	3 points	2 points	7 points

Table 10: Go Green and Go Green Plus Ranking Criteria Summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
BOMA Go Green Go Green Plus (U.S. and Canada)	1 point: Addresses the criteria by prompting action but without measuring carbon or setting an energy minimum	1x2= 2 points	$750 to $700 for self assessment and verification	3 points: Low cost	Good North American market adoption and the provider plans to respond to user needs	2 points

For buildings that have completed energy audits there is not a great deal of additional GHG reductions offered by using Go Green or Go Green Plus. The same could also be said for BOMA as the system does not require close analysis of an existing building's operations and maintenance.

3.1.4 Building Research Establishment Environmental Assessment Method (BREEAM)

As part of a mandate from the UK Government, the Building Research Establishment (BRE) has developed specific tools and packages for sustainable development.

For the purposes of design of new buildings and the renovation of existing ones, BRE developed the BRE Environmental Assessment Method (BREEAM) rating system in 1990, in conjunction with a series of targeted guidelines and working methodologies that have since been integrated into the British building code. Part L of the U.K. building code stipulates regulations on energy use and has recently been updated. Included in Part L are regulations governing the following:

- Energy Performance of Buildings
- Methodology of calculation of the energy performance of buildings using the Standard Assessment Procedure (SAP 2005)

- Consequential improvements to energy performance
- CO2 emission rate calculations
- Quality of Construction including testing
- Operations + maintenance info

BREEAM uses the Standard Assessment Procedure (SAP) as its energy performance standard. SAP is a detailed assessment method that incorporates many variables into the data that drives the final rating, a scale from 1 to 100, where 100 is zero net carbon emission. This is very similar to an EnerGuide rating.
SAP covers the following categories:

- Dwelling dimensions
- Ventilation rate
- Heat losses
- Domestic hot water
- Internal gains
- Solar gains + utilization factors
- Mean internal temperature
- Degree days
- Space heating requirements
- Total energy use + fuel costs
- Energy cost rating
- CO2 emissions + primary energy
- Building regulations

There are 5 performance levels and for each standards (such as water or energy). The performance levels are as follows:

- Pass (P)
- Good (G)
- Very Good (VG)
- Excellent (E)
- Outstanding (O)

The rating system functions much like an International Standards Organization (ISO) certification and requires a great deal of documentation. The BREEAM Assessor Manuals are technical guidance documents that aid licensed BREEAM Assessors in carrying out project assessments.

The number of credits achieved under the energy section is determined by comparing the building's CO2 index (EPC Rating) taken from the Energy Performance Certificate (EPC). There is no energy or CO2 minimum for buildings that are less than VG (Very Good). The minimum standard for an E (Excellent) rating is an EPC index of 40 for new buildings and 47 for existing buildings.

The cost for an assessment is approximately £1,500 (approximately Canadian $3,000); however there are no assessors in Canada.

Table 11: BREEAM summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
BREEAM (U.K.)	SAP 2005	Excellent rating= EPC of 47	6 points	2 points	0 points	8 points

Table 12: BREEAM ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
BREEAM (U.K.)	3 points: Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement & raise the energy minimum but regional accuracy will be for the U.K.	3x2= 6 points	Approximately $3,000 Canadian	2 points: Moderate cost	No North American market adoption unable to respond to user needs	0 points

3.1.5 Passive House

The Passive House (Passivhaus in German) program was developed by the Passivhaus Institute in Germany in 1996 and is a rigorous, voluntary standard for energy use reduction in buildings. The goal of the program and associated methodology is to achieve ultra-low energy buildings that require little energy for space heating or cooling. The voluntary standard is not confined only to houses. Several office buildings, schools, kindergartens and a supermarket have also been constructed to the standard. Although it is mostly applied to new buildings, it has also been used for building refurbishments.

Since the inception of the tool, more than 6,000 Passivhaus buildings have been constructed in Europe, most of them in Germany and Austria, with others in various countries world-wide. In North America, the first Passivhaus was built in Urbana, Illinois in 2003, and the first to be certified was built in Waldsee, Minnesota, in 2006. The Passive House Institute U.S. certifies and commissions homes built to the Passive House standard in North America.

A building that achieves the Passive House standard typically includes:

- very good levels of insulation with minimal thermal bridges
- well thought out utilization of solar and internal gains
- excellent level of air tightness
- good indoor air quality, provided by a whole house mechanical ventilation system with highly efficient heat recovery

By specifying these features the design heat load is limited to the load that can be transported by the minimum required ventilation air. Thus, a Passive House does not need a traditional heating system or active cooling to be comfortable to live in - the small heating demand can be typically met using a compact services unit that integrates heating, hot water and ventilation in one unit (although there are a variety of alternative solutions).

Performance characteristics of a Passive House building are:

- Airtight building shell <or= 0.6 ACH @ 50 pascal pressure, measured by blower-door test
- Annual heat requirement <or= 15 kWh/m2/year
- Primary Energy <or= 120 kWh/m2/year

In addition, the following are recommendations varying with climate:

- Window u-value <or= 0.8 Watt/m2/K
- Ventilation system with heat recovery with <or= 75% efficiency with low electric consumption @ 0.45 Wh/m3
- Thermal Bridge Free Construction <or= 0.01 W/mK

These figures are verified at the design stage using the Passive House Planning Package (PHPP). The building science research behind PHPP gives a building's detailed heat load, heat loss and primary energy usage. The latest version of the PHPP also estimates cooling, cooling loads and latent cooling loads. Based on feedback gathered from several completed buildings, the software is frequently refined and incorporates updated calculations for various climates around the world.

The use of "primary energy" allows for a comparison of different buildings independent of the type of energy source. For example, the primary energy factor used in the PHPP software for electricity is 2.7 kWh primary/kWh final. As a result, a building using only electricity would have a 120 kWh/m^2/yr final energy intensity, but a 44 kWh/m^2/yr primary energy intensity. This allows the fuel sources to be factored according to its GHG profile, as most countries in Europe and most U.S. States have power sources that carry a heavy GHG footprint.

The PHPP software contains a series of excel spreadsheets that allow building designers to verify energy demand based on inputting data into cells that calculate the performance characteristics required of a Passive House. The PHPP spreadsheets also measures CO2e using the same emissions factors as LEED NC 1.0 from the CaGBC (electricity at approximately 270 tonnes of CO2e/GWh versus the BC average of 80 tonnes of CO2e/GWh). While the energy performance criteria are rigorous, the PHPP tool appears to constrain design in that it requires designers to limit the use of operable windows and glazing ratios as they are not factored within the software or allowed within the design principles. The software does assume that all HVAC systems will employ heat recovery. The software and design principles assume that only the heat actually stored in the interior air extracted by the ventilation system can be reused in the building and that windows would never be used for ventilation. This would eliminate free cooling and heating from operable windows during shoulder seasons by occupants on the perimeter of the building. As a result, any addition of window ventilation may yield higher than 15 kWh/m^2/yr energy consumption.

While the Passive House standard has been used on only a few buildings greater than 2 stories, its simple requirements could be applied to larger buildings since a secondary school, libraries, warehouses and postsecondary trade school have been certified in Europe. All of these building types typically have low energy intensities, but a building with higher energy intensities such as a lab or academic facility with many computers, may be able to meet some of the criteria of the Passive House Standard. The plug loads in a lab or facility with many computers and servers will typically exceed 120 kWh/m²/yr, but the air tightness and heating demand criteria of Passive House could be met.

The PHPP software costs approximately $180 and the cost for a Passive House rating is approximately $1,500 for a 2000 SF home, and for larger projects the cost will proportionately increase. The institute requires construction photos and a signed statement by the contractor that everything has been built according to the drawings and specifications provided for review. A blower-door test result from an independent agency is required to prove that the building complies with the specified air tightness requirement. The Institute then files all the information provided, verifies it and issues the certificate "Quality Approved Passive House" if all criteria are met.

Table 13: Passive house summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
Passive House	Energy Intensity	Maximum Energy <120 kWh/m²/yr	6 points	3 points	0 points	9 points

Table 14: Passive house ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
Passive House	3 points: Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement and raise the energy minimum.	3x2= 6 points	Approximately $1,700 for a 2000 ft2 home including design tools	3 points: Low cost	No North American market adoption unable to respond to user needs	0 points

3.1.6 Green Star

Green Star is an Australian national, voluntary environmental rating scheme that evaluates the environmental design and achievements of buildings. Green Star was developed for the property industry in 2003 by the Green Building Council of Australia (GBCA) in order to establish a common language and set a standard of measurement for green buildings.

Green Star covers a number of categories that assess the environmental impact that is a direct consequence of a project's site selection, design, construction and maintenance. The nine categories included within all Green Star rating tools are:

- Management
- Indoor environment quality
- Energy
- Transport
- Water
- Materials
- Land use & ecology
- Emissions
- Innovation

These categories are divided into credits, each of which addresses an initiative that improves or has the potential to improve the environmental performance of a building. Points are awarded in each credit for actions that demonstrate that the project has met the overall objectives of Green Star.

Once all claimed credits in each category are assessed, a percentage score is calculated and Green Star environmental weighting factors are then applied. Green Star environmental weighting factors vary across Australia's states and territories to reflect diversity of environmental concerns.

The following Green Star Certified Ratings are available:

- Star Green Star Certified Rating (score 45-59) signifies 'Best Practice'
- 5 Star Green Star Certified Rating (score 60-74) signifies 'Australian Excellence'
- 6 Star Green Star Certified Rating (score 75-100) signifies 'World Leadership'

Although Green Star certification requires a formal process, any project can freely download and use the Green Star tools as guides to track and improve its environmental performance. A project cannot publicly claim or promote a Green Star rating or use the Green Star rating logo unless the GBCA has validated the project's achievement through a formal assessment process.

Green Star Certification is a formal process that involves a project using a Green Star Rating Tool to guide the design or construction process during which a documentation-based submission will need to be collated as proof of this achievement. The GBCA will commission a panel of third-party Certified Assessors to validate that the documentation is in compliance with all the claimed credits. There are two rounds of third party assessment available to a project. If the desired Certified Rating is not awarded in the first round, a project may, in limited circumstances, be eligible to appeal the certification.

Under the energy section, the Energy Calculator measures CO2 in kg/CO2e-m²/annum as assessed by the Australian Building Greenhouse Rating (ABGR) Validation Protocol. A lower CO2 footprint will result in more points awarded. It is required that a project emit no more than 110 kg/ CO2e-m²/annum to be eligible for a Green Star rating. This means that the energy intensity value (measured in kWh/m²/yr) will vary by state in order to meet the national minimum CO2 intensity (measured in kg/ CO2e-m²/annum). The energy calculator only has emissions factors for states in Australia. In certain states the CO2 emissions factors for gas are not available for the purposes of the calculator. In that case a higher national average is used. If a project does not emit CO2, then the project receives the maximum score of 20 points.

The cost of assessment is between $4,000 and $18,000

Table 15: Green star summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
Green Star (Australia)	ABGR Validation Protocol	110 kg/ CO2e-m²/ annum or 117 kWh/m²/yr	6 points	1 point	0 points	7 points

Table 16: Green star ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
Green Star (Australia)	3 points: Addresses the criteria by measuring carbon and the provider plans to add regional accuracy to carbon measurement and raise the energy minimum.	3x2= 6 points	$4,000 to $18,000 to register and certify	1 point Moderate cost	No North American market adoption unable to respond to user needs	0 points

Australian dollars (approximately $3,900 -$17,560 Canadian dollars).

3.1.7 The Living Building Challenge

The Cascadia Region Green Building Council (a cross border chapter of the CaGBC & USGBC) in 2006 issued a challenge to all building owners, architects, design professionals, engineers and contractors to build in a way that provides for a sustainable future. While the program is referred to as a "challenge", the Cascadia Region Green Building Council will issue "Living" status to buildings that achieve all performance areas of the challenge.

The Living Building Challenge is comprised of six performance areas or petals: site, energy, materials, water, indoor quality, and beauty & inspiration. Projects may apply for an individual petal designation by satisfying the requirements within that petal or for Living Building Status by attaining all requirements within the system. There are 3 rules to the challenge.

1. All elements of the Living Building Challenge are mandatory.
2. Many elements have temporary exceptions to acknowledge current market limitations. These exceptions will be modified or removed as the market evolves.
3. A Living Building designation is based on actual, rather than modeled or anticipated performance. Therefore, buildings must be operational for one year prior to being evaluated.

The energy requirement for the Living Building Challenge is for net zero energy performance. There is no particular method outlined for achieving this goal. Any building meeting the Living Building Challenge would also be carbon neutral. The Living Building Challenge User's Guide makes allowances for "project" or "site" net zero energy.

While it is called a "challenge", the Living Building program does constitute a rating system, the certification process for achievement will likely resemble that of LEED with a lower cost of certification and less submitted documentation. The Cascadia Region GBC has indicated that registration will be $100 and certification will likely cost between $2,500 to $7,000.

While all the requirements of the Living Building Challenge may not be relevant or achievable at this time, UBC may consider pursuing the energy prerequisite for a number of building projects underway on campus.

4.0 ENERGY STANDARDS AND CODES

Over the past couple of years, several new codes and standards have been launched into the market place. Although these standards and codes do not necessarily constitute a green building rating system, they provide

Table 17: Living building summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
Living Building Challenge (North America)	None	Net zero energy	8 points	1 point	0 points	9 points

Table 18: Living building ranking criteria summary.

Rating System	Criteria #1 CO2 Reduction		Criteria #2 Cost		Criteria #3 Market Adoption	
Living Building Challenge (North America)	4 points: Fully addresses the criteria of reducing carbon but does not provide regional tools for measurement	4x2= 8 points	$2,500 to $7,000 to register and certify	1 point Moderate cost	No North American market adoption unable to respond to user needs	0 points

a framework for reducing a building's energy consumption or GHG emissions. It may be possible for UBC to adopt one or more elements discussed in this section and use some of the strategies within the codes for future building design guidelines.

4.1 Architecture 2030 Challenge

The 2030 Challenge was issued in 2006 by Ed Mazria from the Architectural Institute of America (AIA) to the entire building industry and sets a new standard for energy reduction in buildings. The initial phase of the Challenge, a 50% reduction of fossil fuel based GHG emissions, is designed to bring an immediate halt to the increase of GHG emissions in the building sector; subsequent phases are designed to incrementally and systematically reduce CO2 emissions in this sector.

The fossil fuel reduction standard for all new buildings according to the 2030 Challenge is:

- 60% in 2010
- 70% in 2015
- 80% in 2020
- 90% in 2025
- Carbon-neutral in 2030 (using no fossil fuel GHG emitting energy to operate)

The 2030 Challenge has been adopted by the:

- US Conference of Mayors (USCM)
- National Association of Counties (NACo)
- American Institute of Architects (AIA)
- US Green Building Council (USGBC)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (supporter)
- International Council for Local Environmental Initiatives (ICLEI)
- Congress for the New Urbanism (CNU)
- States of Illinois, Minnesota, California and New Mexico
- Numerous consulting firm and other organizations

Although slower to act, the U.S. Federal Government has started to adopt the 2030 Challenge targets for all new and renovated federal buildings.

The energy standard is based on the Commercial Building Energy Consumption Survey (CBECS). CBECS is an American sample survey that collects information on the stock of U.S. commercial buildings, energy-related building characteristics and energy consumption and expenditures. Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial or agricultural, so it includes building types that might not traditionally be considered "commercial", such as schools, correctional institutions and buildings used for religious worship. CBECS is not universally used in the U.S. and, therefore, Architecture 2030 issued a code equivalency guideline as outlined in the table below.
The 2030 Challenge only requires building be net zero

Table 19: Architecture 2030 Challenge code/standard equivalency summary.

CODE / STANDARD	COMMERCIAL	RESIDENTIAL
ASHRAE 90.1-2004	30% below	
ASHRAE 90.1-2007	25% below	
ASHRAE 189 (in progress)	0	
IECC 2006	30% below	30% below
California Title 24 2005		15%-20% below
California Title 24 2008	10% below	
Oregon Energy Code	25% below	30% below
Washington Energy Code	25% below	25% - 30% below
RESNET HERS Index		65 or less
LEED NC 2.2 / Homes	New-EA Credit #1:6 pts	
Renovation-EA Credit#1:8 pts	HERS Index: 65	
LEED 2009 (in progress)	New-EA Credit #1:7 pts	
Renovation-EA Credit#1:9 pts		
GBI Standard (in progress)17	PATH A, 8.1.1.1:15 pts	
EECC Option (prescriptive path)		EC-154
NBI Option (prescriptive path)	New- Core Performance w/ enhanced measures	

CO_2 emissions (as measured from fossil fuel based sources) whereas the Living Building Challenge requires a net zero energy building.

The 2030 Challenge only applies to GHG emissions generated by fossil fuel based energy sources. The implication is that projects in B.C. that use wood as a heating source would not need to measure their CO_2 footprint. It also means that low GHG emissions sources of electricity like those in B.C. would not be part of the measured energy under this challenge.

4.2. U.K. Energy Performance Certificate Program

The United Kingdom has begun a rigorous program of building certification that acts much the same way as a food labelling program. The concept is that a building must meet the Building Regulations 2000 standard for energy efficiency before it can be sold. The energy performance certificates are required for new and existing buildings and must be presented at the time of purchase or rental of any building.

According to the program requirements, the energy performance certificate must fulfill all the standards as set out in “Requirements for the energy performance standards at the point of purchase for England and Wales”.

The Building Regulations 2000 standard was used as a template to rate elements of the building’s energy efficiency. The nine elements that are rated include:

1. Main walls
2. Main roof
3. Main floor
4. Windows
5. Main heating
6. Main heating controls
7. Secondary heating
8. Hot water
9. Lighting

The elements are rated much like a school report card. A building can get a “D” with regards to its energy efficiency because of poor insulation and single glazed windows. The score card will show the total energy use in kWh/m^2 per year as well as lighting cost and heating costs per year. The certificates will also state the predicted CO_2 emissions per year for the building.

Enforcement of the new Energy Certificates will become the responsibility of the local authorities that currently enforce building standards in the country. In the case of larger cities like London or Manchester, the city is responsible for enforcement of the new energy standard, while in more rural areas the county will be enforcing the new standard using teams of assessors. This “energy performance standard at the point of purchase” is one of the most interesting and innovative ways in which to address the energy performance of the extensive existing building market in the U.K.

In Germany, a similar system has been adopted, which is known as the Energie Pass (or Energy Passport). All European Union members must create a similar program as part of the EU’s Energy Directive. While the U.K. example is older, the German Energie Pass website contains more resources and tools for people to understand the system.

4.3 American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) 90.1

The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) has always been leaders of energy standards. The most current energy standard of ASHRAE 90.1-2007 improves upon past iterations of the standard. ASHRAE 90.1 is based on a percentage energy reduction over baseline conditions, which provides minimum energy efficiency design requirements for buildings under four storeys. The baseline is set for various building types and is usually modeled using EE4, DOE-2, TAS and E-quest software tools.

The newest standard being developed for ASHRAE is the Sustainable Buildings Standard 189 (which will exclude low-rise residential buildings). Standard 189 is not a building rating system, but rather a compilation of criteria that must be met in order for local building code officials to provide a certificate of occupancy for a facility. The proposed standard ASHRAE 189 will focus on-site renewable power generation instead of high-performance, green buildings relying completely on conventional energy sources. The standard encourages projects to produce a minimum percentage of their peak electrical load through on-site generation such as by photovoltaic panels or equivalent solar water heating systems.

Energy efficiency is also a large part of the standard. There is a goal for projects to achieve a minimum of 30% reduction in energy cost (and carbon dioxide equivalent) over that in ASHRAE 90.1-2007 - Energy Standard for Buildings except low-rise residential buildings.

4.4 Model National Energy Code for Buildings (MNECB)

The MNECB was prepared under the auspices of the Canadian Commission on Building and Fire Codes and was first published in 1997 by the National Research Council Canada (NRC). The MNECB applies to all buildings, other than houses of three storeys or less, and to additions of more than 10 square metres to such buildings, and was designed to create a nationwide standard. While the standard has never been adopted by provinces or territories it remains both as a LEED Canada NC 1.0 reference standard and the nation's energy standard.

The MNECB provides maximum thermal transmittance (1/RSI or U) levels for building envelope components per type of energy (oil, natural gas, electricity, wood, propane) for different regions of Canada. These levels were determined using regional construction and heating energy costs in a life-cycle cost analysis. As well, the MNECB gives regional U-values for windows, references energy-efficient equipment standards and identifies when heat recovery from ventilation exhaust is required for dwelling units. To allow flexibility in achieving a minimum level of energy efficiency, the code offers three compliance approaches: a Prescriptive Path, a Trade-off Path and a Performance Path.

The next edition of the MNECB is scheduled to be released in 2011, and will offer new information to facilitate the evaluation of innovative products and systems.

4.5 Energy Star

Energy Star is an international standard for energy efficient consumer products and buildings, first created by the US Environmental Protection Agency (EPA) in 1992. Since then Australia, Canada, Japan, New Zealand, Taiwan and the European Union have adopted the program. Devices carrying the Energy Star logo, such as computer products and peripherals, kitchen appliances, buildings and other products, save 20%-30% on average. However, many European-targeted products are labeled using a different standard, Telecommunication Certification Officer (TCO) Certification. This certification is based on a combined energy usage and ergonomics rating from the Swedish Confederation of Professional Employees instead of Energy Star.

According to the Environmental Protection Agency, Energy Star buildings use at least 15% less energy than standard buildings. Energy Star rated buildings usually include properly installed insulation, high performance windows, tight construction and ducts, energy efficient cooling and heating systems and Energy Star appliances, lighting and water heaters.

The LEED EB Operations and Management and EB 2.0 rating systems use the Energy Star Portfolio manager to track and rate buildings. The Portfolio Manager is an interactive energy management tool that allows project managers to track and assess online the energy and water consumption across an entire portfolio of buildings. Most commercial and institutional facilities can rate their energy performance on a scale of 1–100 relative to similar buildings across the U.S. The building analyzed is not compared to the other buildings entered into Portfolio Manager to determine an Energy Star rating. Instead, statistically representative models are used to compare the building against similar buildings from a national survey conducted by the Department of Energy's Energy Information Administration. The national survey, known as the Commercial Building Energy Consumption Survey (CBECS), is conducted every four years and gathers data on building characteristics and energy use from thousands of buildings across the United States. A building's peer group is compared to buildings in the CBECS survey that have similar building and operating characteristics. A rating of 50 indicates that the building, from an energy consumption standpoint, performs better than 50% of all similar buildings nationwide, while a rating of 75 indicates that the building performs better than 75% of all similar buildings nationwide. Buildings with a rating of 75 or greater may qualify for the Energy Star label.

While buildings in Canada can be analyzed using the Portfolio Manager, they can not be awarded an Energy Star rating because the data is based on American buildings. The Canadian EnerGuide Program functions in conjunction with the American Energy Star program. The Energy Star website offers a number of other resources. There is a building upgrade calculator, a financial value calculator and a cash flow opportunities calculator. To date, there are no resources for calculating GHG emissions.

4.6 E-Benchmark

E-Benchmark is a U.S. based energy standard that has been developed by the New Building Institute (NBI). NBI developed the E-Benchmark following a set of requirements largely based on the ANSI procedures for the Development and Coordination of American National Standards. E-Benchmark can be used as a stand alone system for individual projects or as a basis for high performance building programs sponsored by non profits, government agencies, utilities and others. As a stand alone system, E-Benchmark allows design teams to document compliance through a process of self-evaluation or through a certified third party commissioning agent.

E-Benchmark's criteria were designed to be compatible with LEED and other sustainable or green building programs. For design teams the criteria can assist in obtaining full or partial LEED credits. A separate guide is being developed to provide a more detailed description of how the E-Benchmark standard will work with the LEED system.

The basic criterion for the E-Benchmark tool allows a project to pursue either a prescriptive or simulation path under ASHRAE 90.1. If pursuing the prescriptive path, projects must achieve 10%-30% better than ASHRAE 90.1 and if using the simulation path 30% to 50% better than ASHRAE 90.1. A basic guide for steps to be followed during various stages of the design and construction are contained within the guide to help project teams meet the prescriptive or simulative targets. This tool is not applicable to hotels, motels and residential buildings as it does not have a defined criteria for 24-hour residential or guest room process loads.

4.7 Standard Assessment Procedure (SAP) 2005

The Standard Assessment Procedure was developed in 2005 by the Building Research Establishment (BRE). The indicators for energy performance under SAP 2005 are energy consumption per unit floor area, an energy cost rating (the SAP rating), an Environmental Impact rating based on CO2 emissions (the EI rating) and a Dwelling CO2 Emission Rate (DER).

The SAP rating is based on the energy costs associated with space heating, water heating, ventilation and lighting, less cost savings from energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The SAP rating is expressed on a scale of 1 to 100, the higher the number the lower the running costs of the building.

The EI rating is based on the annual CO2 emissions associated with space heating, water heating and ventilation and lighting, less the emissions saved by energy generation technologies. The EI rating is adjusted for floor area and is expressed on a scale of 1 to 100, the higher the number the better the standard.

The DER is a similar indicator to the EI rating, which is used for the purposes of compliance with building regulations. It is equal to the annual CO2 emissions per unit floor area for space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies, expressed in kg/m²/year.

BRE uses SAP to measure a project's energy cost, CO2 emissions and emissions per m² for dwelling units. The method of calculating the energy performance and the ratings is set out in the form of a worksheet, accompanied by a series of tables. The methodology is compliant with the Energy Performance of Buildings Directive that all European Union countries must use.

5.0 SUMMARY OF RATING SYSTEM COMPARISON AND CONCLUSION

Based on the analysis completed in section 4 and as outlined in the following tables below, there is no single green building rating system that would perfectly meet the needs of reducing CO2 emissions from new or existing buildings and becoming GHG neutral. Most of the minimum performance thresholds for energy conservation or efficiency within the green building rating systems are set low in order to encourage market transformation and adoption.

5.1 New Building Rating System

The table on the next page summarizes the ranking of each system applicable for new buildings.

The LEED NC, CS and CI rating systems along with the Passive House and Living Building systems score the highest with 9.5, 9.0 and 10 points respectively. The biggest advantage of LEED-Canada over Passive House and the Living Building Challenge is that the CaGBC and USGBC have gained widespread market adoption in North America and LEED has been applied to a diversity of building types. In addition, the CaGBC and USGBC are actively working to improve the system and has created tools for campuses in Canada.

Table 2 revealed that the energy intensities of LEED buildings are not altogether different from the final energy intensities of Passive House buildings. The Passive House tools have not gained widespread adoption in the North American market place. For example, there are currently no laboratories, lecture theatres or other academic buildings constructed to the Passive House standards in Europe or in North America. Lastly, the tool uses a European rate for establishing energy primary intensity. The standard does have some very useful guidelines for air tightness that are missing from the

LEED reference guide and could be applied on LEED projects for greater energy performance.

The Living Building Challenge sets aggressive and laudable goals for buildings to achieve net zero energy. At present, no buildings that have been constructed to the Living Building Challenge standards and only a small number of zero energy buildings exist worldwide. A very progressive client may wish to pursue the Living Building Challenge prerequisite for net zero energy.

Based on the above analysis, LEED Canada NC continues to be the leader when constructing new buildings as the LEED Letter Templates attempt to measure the GHG footprint of buildings.

5.2 Existing Building Rating System

The Table below summarizes the ranking of each system applicable for existing buildings.

The LEED EB-O&M rating system scores the highest of the 4 rating systems surveyed with 10.5 points. The biggest advantage of LEED EB-O&M is that it rewards building owners for tracking and reporting on CO2 emissions. The LEED EB-O&M system requires the measurement of least 2 energy loads such as lighting and plug loads, which would enable most clients to build upon their existing metering program and pinpoint areas for demand side reductions.

5.3 Conclusion

Due to its wide marketplace acceptance, familiarity in the construction industry and effectiveness at reducing GHG emissions, the Leadership in Energy and Environment Design for New Construction (LEED® NC) green building rating system is best suited to meet a client's goals for reducing its carbon emissions from buildings while achieving a recognizable industry rating. LEED NC provides a framework for tracking and rewarding low energy use and total carbon emissions reductions,

Table 20: Rating system ranking summary.

Rating System	Energy Standard	Energy Minimum	Criteria #1 CO2 Reduction	Criteria #2 Cost	Criteria #3 Market Adoption	Total Score
LEED EB-O&M (U.S. and Canada in 2009)	Energy Star or EnerGuide	20% better than National Average	6 points	1.5 points	3 points	10.5 points
LEED NC / CS or CI (Canada)	ASHRE 90.1 and MNECB	35% better than ASHRE, 42% better than MNECB	6 points	0.5 points	3 points	9.5 points
BOMA Go Green/ Go Green Plus (U.S. and Canada)	Energy Audit	None defined	2 points	3 points	2 points	7 points
BREEAM (U.K.)	SAP 2005	Excellent rating= EPC of 47	6 points	2 points	0 points	8 points
Green Star (Australia)	ABGR Validation Protocol	110 kg/ CO2e-m²/annum or 117 kWh/m²/yr	6 points	1points	0 points	7 points
Green Globes Existing	MNECB	40% better than MNECB	4 points	3 points	1 points	8 points

however the current version of these systems track carbon emissions using North American averages that are higher than the provincial or state averages.

While the remaining new building rating systems analyzed scored well in certain areas, all the rating systems analyzed have a common shortcoming with regards to measuring carbon. None of the rating systems analyzed have the tools to accurately measure carbon on a state or provincial level. The primary reason for recommending LEED NC is that it most accurately measures carbon reductions using North American data. The CaGBC and USGBC have a track record of responding to industry demands and is the most well equipped organization to respond to a client's requirements for accurate GHG emissions reduction measurement. The organizations behind the other rating systems analyzed in this report do not have the industry support or track record of performance in the North American marketplace that the CaGBC and USGBC do with LEED.

The short list of existing building rating systems had the same shortcoming with regards to measuring carbon. Only LEED EB-O&M had a credit for tracking and measuring carbon emissions and their reductions. The primary reason for recommending LEED EB-O&M is that the CaGBC and USGBC are currently adapting it for the North American marketplace. LEED EB-O&M, in its current form, would most likely result in greater GHG reductions than Green Globes or BOMA Go Green, which do not require load specific metering and demand side reduction tracking.

REFERENCES

[1] AIA Sustainability Discussion Group, (2008). "Quantifying Sustainability: A Study of Three Sustainable Building Rating Systems and the AIA Position Statement", Report, Retrieved on 4/2009 from http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aias076586.pdf.

[2] Smith, T. M., Fischlein, M., Suh, S., Huelman, P., (2006). "Green Building Rating Systems: A Comparison of the LEED and Green Globes Systems in the US", Report, Retrieved on 4/2009 from http://www.foresthealth.org/pdf/LEED%20Comparison%20Study.pdf.

[3] Gavi, K., (2004). "Green Rating Systems: An Overview", ASHRAE Journal, pp. 56-59, Retrieved on 4/2009 from http://www.energycodes.gov/implement/pdfs/Sustainability.pdf.

[4] Olson. S., Arny, M. and Eisch, E., (2006). "Sustainable Building Rating Systems Addressing Building Maintenance and Janitorial Products, Policies and Methods", Report, Leonardo Academy, Retrieved on 4/2009 from http://www.leonardoacademy.org/download/Janitorial%20Products%20and%20Building%20Certification.pdf.

[5] Turner, C. and Frankel. M., (2008). "Energy Performance of LEED for New Construction Buildings", Report, New Building Institute, Retrived on 4/2009 from http://www.usgbc.org/ShowFile.spx?DocumentID=3930.

04.
QUANTIFIABLE BENEFITS OF ACCESS TO NATURE IN BUILDINGS
Sky Garden Analysis for a Commercial Office Tower

Michelle Halle Stern, AIA, P.E., LEED Faculty™, *michelle.hallestern@perkinswill.com*
Tom Mozina, AIA, LEED® AP, *tom.mozina@perkinswill.com*
***Gail Borthwick, AIA, LEED® AP** *(*while previously at Perkins+Will), gailborthwick@smithgill.com*

ABSTRACT
"Sky garden" is the term given for vertically stacked, three-story tall landscaped interaction hubs, flanked by formal and informal conference spaces. The design intent of the sky garden is to create an environment that serves as a tool for increasing business performance. A literature review was conducted to determine if that premise is supported by scientific evidence.

Studies in the literature examined benefits from access to nature either by personal experience, images or by exterior views within office and healthcare environments and in laboratory settings. Research showed benefits for access to nature in the following three categories:

- Performance indicators include improved opportunities for collaboration and communication, positive impact on recruiting and retention, positive message about investment in staff, which equates to trust building, alignment in key workplace initiatives and notable marketplace differentiator in leased environments.
- Psychological indicators include stress reduction, increased mental agility and innovative thinking, positive perceptions, background noise management, increased motivation and productivity.
- Physiological indicators include improved air quality and daylighting, increased humidity, reduced absenteeism, dust, carbon dioxide, mold, bacteria and chemicals.

KEYWORDS: nature, productivity, health, performance, indoor environment, indoor air quality, stress

1.0 INTRODUCTION
The increased focus and awareness on sustainable design has sparked a renewed interest in research that examines not only building performance, but the impact that poor workplace design has on its occupants. It is accepted knowledge that elevated levels of workplace stress, noise, varying comfort conditions (i.e. temperature, humidity, etc.) and poor indoor air quality have a direct impact on worker health (increased absenteeism) and performance.

In light of this perception the owner of a 1.1 million gross square foot [GSF] corporate office tower was considering sky gardens on its associate floors. The client wanted to base their investment decision on documented benefits.

For this paper "sky garden" refers to vertically stacked, three-story tall landscaped interaction hubs, flanked by formal and informal conference spaces. The design intent of the sky garden is to create an environment that serves as a tool for increasing business performance.

A literature review uncovered several potential benefits of providing this type of solution. They include improvements on individual and group performance and in key psychological and physiological indicators.

Performance indicators include improved opportunities for collaboration and communication, positive impact on recruiting and retention, positive message about investment in staff, which equates to trust building, alignment in key workplace initiatives and notable marketplace differentiator in leased environments.

Psychological indicators include stress reduction, increased mental agility and innovative thinking, positive perceptions, background noise management, increased motivation and productivity.

Physiological indicators include improved air quality and daylighting, increased humidity, reduced absenteeism, dust, carbon dioxide, mold, bacteria and chemicals.

While these potential benefits are quite positive, given the competing need to maximize facility utilization in other ways, the research question was whether it was appropriate to include one or two sky gardens. The question is quantifiable as investing 18,000 square feet [SF] for both, versus investing 10,000 SF for only one. For the two sky garden option, they would be located on opposing corners of the building and on alternating floors so that the benefits of the amenity are experienced across the entire office floor plate.

2.0 PROBLEM

The purpose of this paper is to examine the degree to which the benefits of the sky garden may be assessed in order to determine whether the additional 8,000 SF is a good investment. In order to better understand the value of the investment, the design team conducted a literature review of studies and case studies that examined the benefits of access to nature in buildings.

3.0 METHODOLOGY

The method for this research was to examine published research and building case studies in three areas of study: work performance indicators, psychological indicators and physiological indicators. The working assumption was that features that have the potential for a positive impact on employees [improving performance, health, comfort, etc.] will provide a positive return on investment. Moreover, providing parity in access to these types of features is an important aspect of assuring the benefits. In addition to the literature review, research included area analyses and construction cost estimates.

4.0 RESEARCH STUDIES

4.1 Work Performance Enhancements

- BMW cites “the human factor is the No. 1 criterion in determining a company’s relative success. Accordingly, we see our associates not as a cost factor, but instead as an essential performance factor. This is especially true because any human resources policy that is not oriented towards the associate will always lead to negative cost effects in the long run, thus proving uneconomical.”[1]
- Including natural settings has been found to be an effective means to evoke positive market identity[2]
- “Our research shows that a change as simple as adding flowers and plants can be important in the most meaningful way to businesses in the modern economy…people’s productivity, in the form of innovation and creative problem solving, improved – which in certain circumstances could mean the difference between mild and great business success.”[3]
- Hospital staff heavily use gardens for positive escape from work place pressures and to recuperate from stress. Growing evidence has begun to appear that hospital gardens increase staff satisfaction with the work place and may help hospital administrators in hiring qualified personnel.[2]
- When plants were placed in the reception area of a hospital the users perceived it to be more ornate, more interesting, more cheerful, more welcoming, more relaxing, less stressful, more expensive, tidier, quieter. There were no negative findings.[4]
- It is a common human resource rule that in order to attract and retain top employees, the workplace must offer aspects of what inspires employees during “off” time. Gallup polls indicate that two-thirds of the American work force cite gardening as their favorite hobby.
- Providing spaces where people can communicate and interact easily can spur conversations that can help to build trust.
- The investment group Winslow Management Co. manages $225 million in assets for environmental non-profits, pension funds and individuals; found that publicly traded companies that occupy LEED certified buildings outperformed the Dow Jones Industrial Average by as much as 20%.

4.2 Psychological Factors

- Dr. Roger Ulrich is a behavioral scientist, Director of the Center for Health Systems and Design, Texas A&M University. Dr Ulrich is also a professor of landscape architecture and is an internationally recognized expert on the influences of surroundings on human well-being and health. He has concluded that when stress is decreased, then creativity and innovative thinking can flourish.[3]

- Problem-solving skills, idea generation and creative performance improve substantially in workplace environments with interior landscaping. Both men and women demonstrated more innovative thinking in the presence of plants than they did in an environment with art sculpture or no decorative objects.[3]

- Natural settings have been shown to illicit positive emotional states. One's emotional state has been shown to have profound effects on virtually all aspects of thinking including higher and lower-order tasks. Therefore because natural settings elicit positive emotional states, exposure to such environments may facilitate creative problem solving or high-order cognitive functioning via their ability to alter one's emotional state.[5]

- A growing number of studies have shown that exposure to unthreatening natural environments create positive shifts in emotional states – whether the subjects are stressed or unstressed at the beginning of the study. This yields a plausible hypothesis that exposure to positive natural environments should encourage creativity and higher order cognitive function.[5]

- Urban scenes containing prominent vegetation resulted in higher levels of psychological recovery than those without vegetation. It suggests that people were more wakefully relaxed during exposure to natural landscapes.[5]

- Interior plants can absorb, diffract or reflect background noise in buildings, thereby making the environment more comfortable for the occupants thus reducing stress.[6]

- Once the planting was introduced, 93% of the employees working in these areas felt healthier and more motivated to work. They also felt more valued as employees.[1]

4.3 Physiological Factors

- Responding to fatiguing challenges or stressors is accompanied by persistent declines in cognitive functioning or performance. Restoration through exposure to natural settings could be evident in gains in cognitive performance.[7]

- It was found that productivity could be enhanced by as much as 12% in the presence of plants. Study participants also reported feeling more attentive when plants were present.[8]

- Plant transpiration in an office environment creates a humidity level exactly matching the recommended human comfort range of 30% to 60%.[9]

- When the air is too dry, people are vulnerable to colds and flu. When the humidity is too high, people can develop other complaints. Through their natural processes of transpiration and evaporation, office plants add moisture to the dry overheated air often found in sealed office environments. At the same time, studies show that plants do not add moisture in significant amounts when the air is already moist.[8]

- Plants in the office provide an inexpensive method of cleansing the air of chemicals emitted from modern office equipment, such as computers, photocopiers and fax machines. Allowing these gases to build up can cause headaches and irritation to the eyes.[10]

- When plants were included in the offices, study participants were exposed to 13 commonly used foliage plants. The score sum of 12 symptoms was 23% lower during the period when participants had plants in their offices. This translated into a 14% decrease in absenteeism.[11]

- Most absences (30%) had been due to respiratory illness, but once the plants were introduced these figures fell substantially. The study by BMW demonstrated that the improved air quality in the planted offices generally reduced illness.[1]

- Office employees with plants in their offices had less subjective health complaints linked to the room climate than the test persons that had no plants in their office. The symptoms that were reduced the most in the "plants-group" were headache and skin irritation of the face, scalp, ears and hands.[11]

- The United States Green Building Council (USGBC) and the Green Guide for Healthcare (GGHC) recognize the significance of a connection to the natural world. They cite, "Places of respite connected to the natural environment are key elements in defining a supportive, high performance healing environment with proven effects on patient, family, physician and staff well-being and improved clinical outcomes." They award credit to building projects that provide places of respite to connect patients, visitors and staff to the natural environment for 5% of the usable area.[12]

5.0 CASE STUDIES

Research Case Study 1

Study:
'Impacts of Flowers and Plants on Workplace Productivity'[3]

Date: 2003

Researcher: Dr. Roger Ulrich, Texas A&M University

Issue: Do flowers and plants promote innovation, ideas?

Approach

- Eight month study, 101 participants.
- Participants solved creative problems in different typical workplace environments. The various options were: workplaces with either flowers and plants, sculpture, or a control with no added decorative elements.
- Subjects self rated their moods four times, while performing two creativity tasks and one attention demand task.
- Researchers measured how many ideas participants generated. They also measure the originality flexibility of those ideas.. Evaluations were based on Torrence Test of the Creative Thinking and Profile of Mood States.

Results
Both men and women demonstrated more innovative thinking in the environment with flowers and plants.

Men generated a higher number of ideas; 15% more. Alternatively the women generated more creative and flexible solutions.

Conclusion
Flowers and plants have a beneficial impact on state of mind and emotions.

The key to a gaining the competitive edge in the modern economy is a happy, productive work force. Workers' idea generation, creative performance and problem solving skills improve substantially in workplace environments that include flowers and plants.

Quote from Dr. Ulrich: "People's productivity, in the form of innovation and creative problems solving, improved – which in certain circumstances could be the difference between mild and great business success."

Research Case Study 2

Study:
'Interior plants may improve worker productivity and reduce stress in a windowless environment [8]

Date: 1996

Researcher: Virginia Lohr, Washington State University

Issue:
What is the impact of interior plants on human stress and productivity?

Approach

- 96 participants age 19-46 with 78% under 25.
- Study was conducted in a computer lab at Washington State University.
- The room had no windows and was lit with fluorescent lamps. The walls were painted off-white. The only color was the burnt orange desk tops. Temperature and relative humidity were held constant.
- Participants were tasked to hit a key corresponding to a shape on the scrren as quickly as possible. One hundred symbols were shown in a randomized sequence.
- Subjects were randomly assigned to be tested in either the computer lab with plants (floor, table, and hanging) or the lab without plants. Plants were not in a direct line of sight, but rather visible in subject's peripheral view.
- Researcher measured blood pressure, pulse, and emotions using the Zuckerman Inventory of Personal Reactions. Measurements were taken both prior to and after the experiment was completed.

Results
The pre-task test results were similar for both groups. When plants were added to the lab, the subjects were more productive (12% quicker reactions on the computer task). However, the number of errors was not statistically significant between groups. Pulse was the same in both groups and while blood pressure rose in both groups while during the task, the blood pressure of subjects in the room with plants increased less. Subjects also reported feeling more attentive when the plants were present.

Conclusion
Flowers and plants reduce stress levels and increase productivity in an office environment.

Research Case Study 3
Study:
'Effects of Vegetation Views on Stress and Health Indicators'[13]

Date: 1994

Researcher: Dr. Roger Ulrich, Texas A&M University

Issue:
The effects of viewing plants on restoration or recovery from stress and health related indicators or outcomes pertaining mainly to large-sized vegetation such as trees and shrubs rather than to small plants and flowers.

Approach
- One hundred and twenty subjects watched a stress-inducing movie then were randomly assigned to a "recovery" period in which they viewed a non-stressful movie. One group viewed a videotape of urban environments without nature, and the second video showed a green park-like setting.
- Subjects self-rated feelings and four physiological measures: skin conductance, muscle tension, pulse transit time, and heart rate.

Results
Recovery from stress based on feelings and physiological measures was much faster and more complete for the group viewing natural settings. For this group blood pressure, muscle tension, and skin conductance were reduced more quickly and the reduction was also greater than in the control group.

Conclusion
Views of plants and other nature can reduce stress and in certain situations may have beneficial health-related influences.

Research Case Study 4
Study:
'View through a window may influence recovery from surgery (1984) in "Health Benefits of Gardens in Hospitals"[2]

Date: 2002

Researcher: Dr. Roger Ulrich, Texas A&M University

Issue:
Are there health related benefits that patients and staff can realize by simply looking at gardens and plants?
Approach
- Ulrich compared gall bladder surgery patients who had a bedside window view of either trees or a brick wall.
- Subjects were similar in age, weight, general medical history.

Results
Subjects with a "nature view" had shorter hospital stays and suffered fewer minor post-surgical complications. For these patients the staff more frequently recorded positive comments about their conditions. Those with the "wall view received significantly more negative evaluation comments. People with the "nature view" also requested fewer doses of strong narcotic pain drugs.

Findings of other studies in this literature review:
Patients and families report better satisfaction with the healthcare provider and overall quality of care in the presence of indoor and outdoor gardens, plants, or window views of nature.

Conclusion
Viewing gardens can measurably reduce patient stress and improve health outcomes. This is a key factor in the major resurgence in interest internationally in providing gardens in hospitals and other healthcare facilities.

Many healthcare employees use gardens as an effective means for achieving a restorative pleasant escape from work stress and aversive conditions in the hospital. This positive effect results in increases in staff satisfaction with the workplace, which may in turn help hospitals in hiring and retaining qualified personnel.

Building Case Study 1
Project: Genzyme Corporation[14]

Date: 2005

Architect: Behnisch Behnisch and Partners

Issue:
Design of a revitalized office environment for a biotechnology company integrating a diverse range of sustainable systems.

Design Features
The bright atrium, surrounded by interior gardens, seating areas, and cafes is credited with the project's success. This central space visually connects work areas. Employees reported positive effects of these spaces on their well-being.

Results
Joan Wood, vice-president of leadership and organizational development conducted a post-occupancy survey in October of 2005 to assess the impact of the design on employee productivity.

Seventy-two percent of the staff attributed increased output to the daylighting. Genzyme experienced reduced employee turnover. Wood said, "We had an intuitive sense that it would be a nice place to work, but we didn't think about these returns in investment. We've had a 5% lower sick rate and an 88% improved sense of well-being." Survey results showed the following perceptions:

- 75 percent - the clear glass encourages connection between colleagues
- 88 percent - direct views and access to the interior gardens improves sense of well-being;
- 72 percent - lighting features increase alertness and productivity
- 66 percent - the open office plan increases collaboration
- 58 percent - individual control of temperature improves the quality of the environment.

Conclusion
The openness of the Genzyme Center creates spaces that are brighter, transparent and well ventilated. Direct views and access to interior gardens has significantly lowered sick rate, improved productivity and improved employee sense of well-being. Communication and collaboration between employees has increased also.

Building Case Study 2
Project: Commerzbank, Frankfurt, Germany[15]

Date: 1997

Architect: Foster and Partners

Issue:
Develop large scale urban office building that adheres to strict German laws regarding the quality of the work environment and the integration of the sustainable design features.

Design Solutions
The building is triangular in plan with a central atrium. The perimeter office segments are interrupted by four-story tall occupied winter gardens that rotate around the façade of the building on alternating floors. The winter gardens allow vast amounts of light to drop within the building and provide pleasant views to those working deeper within the building.

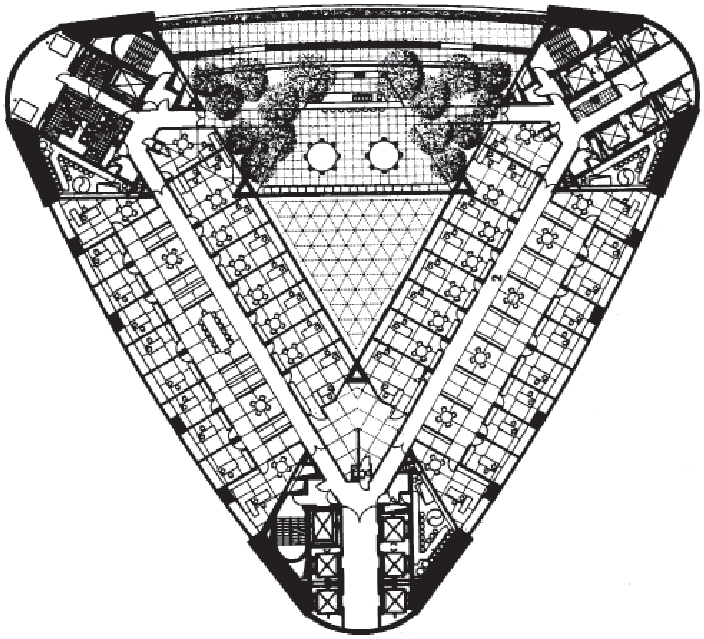
They also provide a buffer zone of insulation between the office and the outdoors. Finally, the garden spaces provide a much more green, natural space for those working in the building which is something lacking in the typical urban work environment.

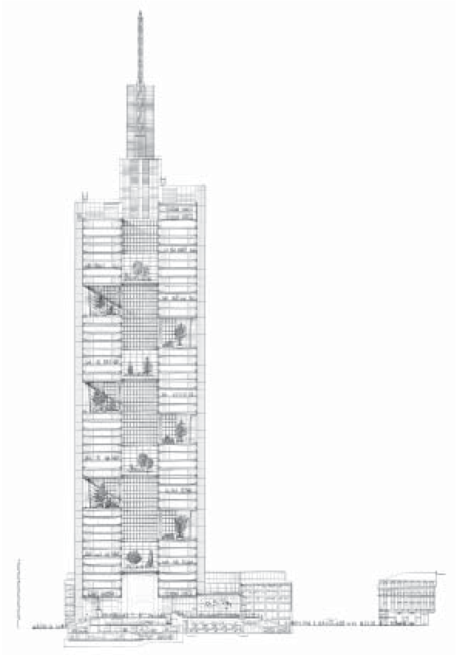
Results
The sky gardens plants purify the air and provide excellent air quality to the tower offices. Plantings were selected based on their orientation and solar exposure, resulting in different microclimates for each sky garden.

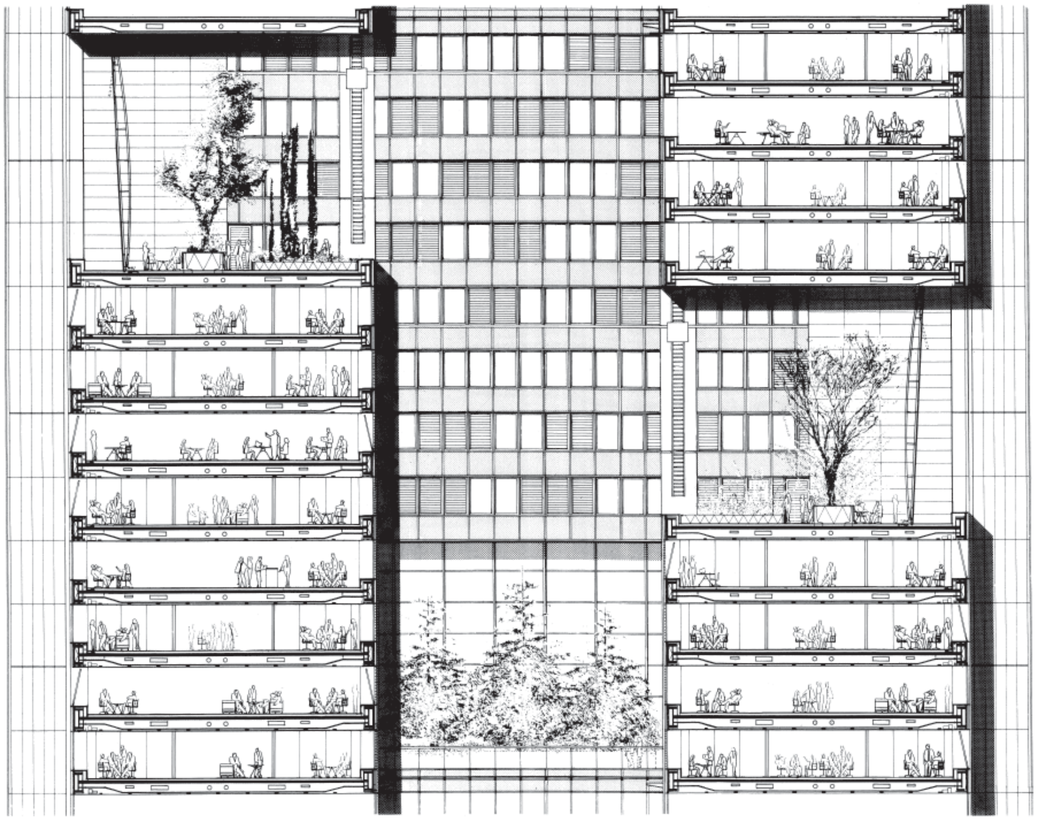
Coneybeare states, "Perhaps the measure of the Commerzbank's success should not be simply in its conceptual popularity, but in the actual figures of the energy saved and increased worker productivity." Proof of increased productivity is yet to be determined, but employees perceive that their productivity has increased and that they do not feel tired when leaving the building.

Conclusion
Strict German laws exist regarding employee comfort in the work environment. Aside from a well ventilated workspace, lighting is of great concern. Virtually all offices must have a window to provide light and a view outside. The building's façade design provides that light in quantities sufficient to make the workplace pleasant.

PROJECT: Commerzbank, Frankfurt, Germany
All Images on this page Courtesy of Commerzbank and Foster + Partners







PROJECT: Commerzbank, Frankfurt, Germany
Drawings Credit: Foster + Partners

Building Case Study 3
Project: BMW, Munich, Germany[1]

Date: 1999

Architect: Karl Schwanzer

Issue:
BMW sponsored a study on the health benefits of interior plants in offices in response to ongoing health complaints from staff at their Munich headquarters.

Process
BMC collected and analyzed extensive data comparing productivity and absenteeism in the planted "green" and the unplanted "non-green" work areas.

Results
The well-being of the work force clearly improved in the planted areas. Beate Klug, the health and safety officer for BMW commented, "once the planting was introduced, 93% of the employees working in these areas felt healthier and more motivated to work. They praised the reduction in noise levels and favoured working in the "green" work place."

Statistics showed that 30% of prior absences were attributed to respiratory illnesses. Once plants were introduced absences fell significantly.

They also found that the plants contributed to better humidity levels, reducing airborne particles and generally making the office more comfortable.

Conclusion
"The human factor is the number 1 criterion in determining a company's relative success. Accordingly, we see our associates not as a cost factor, but instead as an essential performance factor. This is especially true because any human resource policy that is not oriented towards the associate will always lead to negative cost effects in the long run, the proving uneconomical."

Building Case Study 4
Project: Bank, Amsterdam, Netherlands[16, 17]

Date: 1987

Architect: Architectenbureau Alberts Nen Van Huut

Issue:
Reposition the fourth largest bank in the country that was viewed as "stodgy and too conservative."

Process
The board's vision for the building was to be "organic" integrating "art, natural materials, sunlight, **green plants [emphasis added]**, energy conservation, low noise, and water."

Design Features
Despite its organic form the building uses the latest technologies including a specially designed security system and options for individual climate control. It incorporates natural ventilation and passive solar heating. Octagonal interior atriums in the core of each of three towers bring daylight to open plan office spaces. Natural materials such as wood, stone, plants, and water are prevalent throughout the building's interior and exterior. The building is energy efficient using 92% less energy than a conventional building of similar size.

Results
Productivity gains coupled with a 15% reduction in absenteeism. The bank's tremendous growth and large number of employment applications were at least partially attributed to the building's design.

Conclusion
The bold new image of the bank – resulting from the building – is credited with elevating International Netherlands Group from number 4 to number 2 among Dutch banks.

PROJECT: ING Bank, Amsterdam, Netherlands
Photos: Architectenbureau Alberts & Van Huut BV

PROJECT: ING Bank, Amsterdam, Netherlands
Photos: Architectenbureau Alberts & Van Huut BV

6.0 CONCLUSION

As the published research and building case studies show, the benefits of an integrated, landscaped interaction hub within a workplace environment may yield tangible benefits, summarized as follows:

I. Work Performance Enhancements
- Lease market differentiator
- Recruiting and retention tool
- Alignment with the client's corporate workplace initiative
- Investment contributes to trust building
- Increased communication and collaboration

II. Psychological Factors
- Stress reduction
- Increase in innovative thinking
- Increase in mental agility
- Increased motivation
- Increase in productivity
- Positive perception
- Absorption of background noise

III. Physiological Factors
- Reduced illness/absenteeism
- Improved air quality
- Increase in humidity level
- Reduced dust
- Reduction of carbon dioxide
- Removal of chemicals
- Less airborne mold and bacteria
- Daylighting is improved

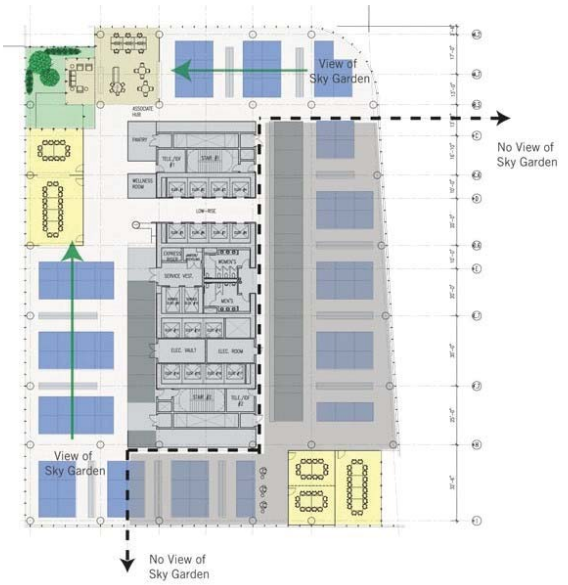
This first goal of this study was to determine the benefits of access to nature. Given the positive evidence, the second objective was to evaluate whether one or two sky gardens were justified. The following discussion outlines the benefits of each option.

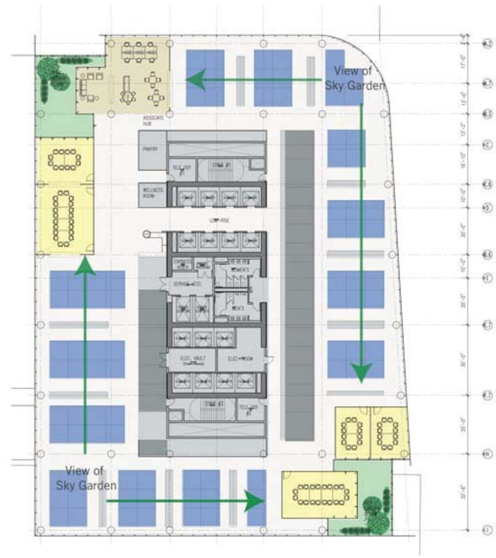
Architecturally providing two sky gardens allows:
- Occupants access to daylight
- Views to natural setting
- Reduction of status corner – more democratic floor plan
- Encouragement of affiliative behavior
- High-rise floor elevator lobbies open directly onto the main conference areas making space more attractive to lease by giving a sense of arrival and connectivity

Comparatively, providing one garden:
- Limits the number of employees with view to a natural setting
- Level of natural daylight is diminished for half of employees
- On high-rise floors the elevator lobby does not open on to the associate hub or main conference room thus leasability is compromised

Given the potential to positively affect 54 personal workstations/offices per floor, the benefits are more easily quantified. As an example, if absenteeism is reduced by one day per year due to the improved environment [a very conservative estimate given the research and case studies just reviewed], and 1,350 associates are involved, that saves 1,350 days per year of lost time. With these and other potential benefits as identified above, the 8,000 SF investment of the second sky garden is clearly quite small comparatively.

Thus, the research justifies the inclusion of two sky gardens in lieu of one in order to give all associates equal access to the benefits of nature in the workplace.





Two Sky Gardens provide a more balanced experience for the tenant.

PROJECT: Floor plans comparing one sky garden to two sky gardens

REFERENCES

[1] ___, "BMW in Munich Goes Green", Retrieved on 12/21/2006 from http://www.plantscapes-officeplants.co.uk/htmlsite/office-plants-bmw.htm.

[2] Ulrich, Roger S., (2002). "Health Benefits of Gardens in Hospitals", for Plants for People International Exhibition, Floriade.

[3] ___, (2003), "University Research Indicates Flowers and Plants Promote Innovation, Ideas", based on study by Ulrich, Roger S., and James Varni, "The Impact of Flowers and Plants on Workplace Productivity" Retrieved on 12/21/2006 from http://plantsatwork.org/pdf/FlowersPlantsProductivity.pdf.

[4] Stiles J., (1995). PhD Dissertation at Oxford Brookes, University, Oxford, England.

[5] Kellert, S. R., and Wilson, E. O. (Eds.), (1993). The Biophilia Hypothesis, Chapter 3, Washington, DC: Island Press.

[6] ___, "Benefits of Office Plants and Interior Landscaping", Retrieved on 12/21/2006 from http://www.plantscapes-officeplants.co.uk/htmlsite/office-plants-benefits.
asp.

[7] Kaplan, R. and Kaplan, S. (1989). "The Experience of Nature: A Psychological Perspective", Cambridge: Cambridge University Press.

[8] Lohr, V. I., Pearson-Mims, C.H. and Goodwin, G.K., (1996), "Interior Plants May Improve Worker Productivity and Reduce Stress in a Windowless Environment", Journal of Environmental Horticulture, Vol. 14, No. 2, pp. 97-100.

[9] Lohr, V. I., (1992). "The Contribution of Interior Plants to Relative Humidity in an Office", in Relf, D., ed., The Role of Horticulture in Human Well-Being and Social Development: A National Symposium, April 19-21, 1990, Arlington, Virginia, Portland, OR: Timber Press, pp. 117–119.

[10] ___, (2002).“The Air We Breathe”, Retrieved on 12/21/2006 from http://www.greenplantsforgreenbuildings.org/pdf/WhattoBuyMH.pdf.

[11] Fjeld, T., Veiersted, B., Sandvik, L., Riise, G. and Levy F., (1998). “The Effect of Indoor Foliage Plants on Health and Discomfort Symptoms among Office Workers”, Indoor Built Environment, Vol. 7, pp.204-209.

[12] ___, (2005). Green Guide for Health Care™. Version 2.1.

[13] Ulrich, R. S., (1994). “Effects of Vegetation Views on Stress and Health Indicators”, Retrieved on 12/21/2006 from www.plants-for-people.org/.

[14] Zeiger, Mimi, (2006). “Bright Green Machine”, Architecture, August 2006.

[15] Coneybeare, Melodie. “Commerzbank Headquarters”, University of Waterloo School of Architecture, Ontario, Canada, Retrieved on 12/21/2006 from http://www.architecture.uwaterloo.ca/faculty_projects/terri/366essaysW03/coneybeare-commerzbank.pdf

[16] Rocky Mountain Institute, “ING Case Study”, Retrieved on 12/21/2006 from http://www.rmi.org/sitepages/pid208.php.

[17] Architectenbureau Alberts & Van Huut BV, internal project summary, Keizersgracht 169 1016 DP Amsterdam, Telephone +31 (0)20 - 622 00 82

05.
CONTEXT BASED DESIGN OF DOUBLE SKIN FACADES

Climatic Considerations During the Design Process

Ajla Aksamija, Ph.D., LEED® AP, *ajla.aksamija@perkinswill.com*

ABSTRACT

This research focuses on investigation of context based design for double skin facades, particularly focusing on climatic considerations during the design process. Double skin envelopes are gaining popularity as a successful methodology for controlling thermal building performance and energy loads. However, their performance in different climates is an important design consideration. If properly designed, they create a buffer zone between the internal and external environment, thus reducing necessary cooling and heating loads. There are several key parameters that influence design and performance, but building location and climate should be prevailing considerations. In this study, double skin façade design strategies are investigated for hot and arid, and cold climates. Building envelope performance is investigated by modeling energy performance of different design scenarios.

KEYWORDS: Double skin façade, energy modeling, climate-based design

1.0 INTRODUCTION

Recent developments in façade technology are following two general trends—trend towards miniaturization, where the focus is on development of thin films, coatings and advanced glazing technologies that improve façade performance on micro-level, and trend toward large-scale double skin façades aimed at improving the macro-level performance. Regardless of the façade type, functional performance goals for any type are similar, primarily separating the indoor from outdoor environments, blocking adverse external environmental effects and maintaining internal comfort conditions with minimum energy consumption. Double skin envelopes are successful in controlling thermal building performance since they create a buffer zone between the internal and external environment. Reduction in energy consumption is directly related to improved thermal performance since lower heating and cooling loads improve energy efficiency.

Design strategies need to adapt according to the climatic condition and take into account local characteristics, such as temperature, solar radiation, humidity level, in order to minimize building loads and energy consumption. The aim of this article is to reflect on strategies for double skin walls that are responsive to particular climate type. The article is structured as follows: initially, general guidelines for double skin façade design are presented as well as past research. Then, two particular designs for double skin walls are investigated, located in hot and arid, and cold climates.

2.0 CLASSIFICATION AND PAST RESEARCH

2.1 Background

The general purpose of the double skin façades is to create a thermal buffer between the interior and exterior environments. They consist of an exterior glazed surface, air cavity and an internal glazed surface, occasionally combined with opaque walls. The air cavity can be ventilated by buoyancy effect (natural convection), by mechanical devices, as well as combination of the two. Selection of the type and ventilation mode depends on the climate, building orientation and design requirements.

Classification of double skin facades can be made according to the geometry and partition type, ventilation mode and air flow type, such as:

- Box window façade: partitioned façade per floor, façade modules are limited to one floor and the cavity is enclosed horizontally and vertically, typically natural ventilation is utilized
- Corridor type: the façade contains large cavity between the two skins, but physically partitioned at each floor level and may extend across several floors without vertical limitations, all three ventilation modes are possible

- Shaft-box façade: similar to corridor type, but connected to vertical shafts for increased use of stack effect, typically utilized for natural ventilation type or hybrid mode
- Multi-story façade: air cavity is open at the top and the bottom, forming large open volume, all three ventilation modes

tion of shading strategies, are also dependant on location and solar radiation, therefore, different strategies should be incorporated for different climates.

Initial cost of double skin facades is obviously higher than single skin façades. However, when considering this façade strategy, life-cycle costs should be taken into consideration. Energy consumption and energy loads

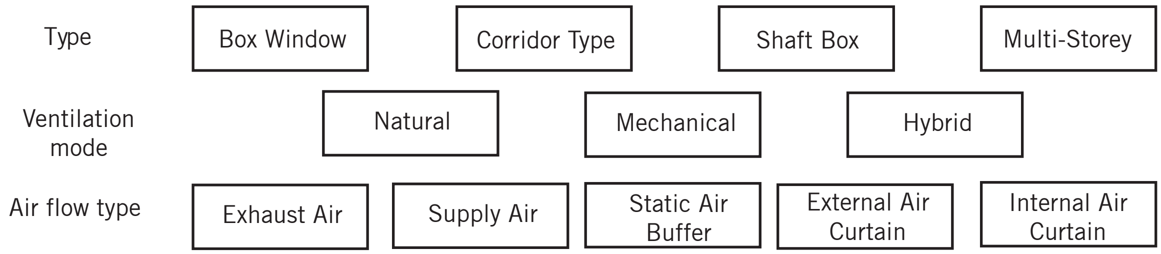


Figure 1: Classification of double skin walls.

There are numerous combinations and design possibilities, varying the partitioning type, ventilation mode and ventilation placement.

Selection of the double skin ventilation mode (natural, hybrid, mechanical) should be based according to building location, while partitioning type based on number of floors, cost and functional requirements. Natural ventilation of the air cavity is applicable to temperate/cold climates, while mechanical ventilation must be used for extreme climates. Hybrid systems are typically utilized in climates that allow this combination, where natural ventilation might be utilized during the colder winter months and mechanical during hot summer months, or even based on daily temperature fluctuations. Air flow type depends on the location and ventilation mode.

Subsequent design decisions are made according to the combination of type, ventilation mode and air flow type. For example, important consideration is glazing type on the interior and exterior skins and it depends on the ventilation mode. If façade is naturally ventilated, insulating double-glazed pane is usually placed as the inner skin to provide thermal break and single pane is placed on the exterior. When mechanical ventilation is utilized, insulating pane is usually placed on the outer skin. Shading devices are typically placed between the two skins to limit the solar gain within the cavity. Choice of glazing properties, such as glazing area, thermal transmittance (U-values), solar energy transmittance (g-value), solar heat gain coefficient (SHGC) and selec-

should be investigated as well as solar control and moderated surface temperatures. Non-energy benefits are wind load reduction, reduced glare, improved daylight and improved acoustic performance[1].

2.2. Effect of Environmental Characteristics on Performance

The majority of double skin façades to date have been utilized in temperate and cold climates. However, there are also examples and studies for warm, hot and arid, and hot and humid climate types[2,3,4]. Blomsterberg reports on several examples from cold and temperate climates that utilize natural ventilation as well as examples from warm climates that utilize natural or hybrid mode. Badinelli reports on a novel double skin and integrated movable shading device, designed for optimum operation for warm regions. Tanaka et al. report on experimental study on the performance of double skin wall with hybrid ventilation system for warm climate. Haase et al. investigated strategies for hot and humid regions and convey that typically double skin walls are ventilated naturally for external air curtains and mechanically for internal air curtains.

A recent research study investigated energy performance of double skin walls within different climates, particularly focusing on effects on cooling and cooling loads[5]. It focused on comparative analysis between double skin façade and a single skin façade for a hypothetical office building. Annual heating and cooling loads were calculated and compared for an office space, located in various types of climates (cold, temperate, warm, hot and arid). The assumed building was considered as a multi-story and hybrid ventilation mode was applied.

Components of the studied double skin included internal layer, composed of 6 mm clear glass pane, 20 mm argon filled gap and 6 mm internal low-e glass and aluminum frame with thermal breaks. External layer consisted of 6 mm clear glass. Components of the single skin were similar, with double glazing composed of 6 mm external clear glass, 20 mm argon filled gap, internal 6 mm low-e glass and aluminum thermal brake frame. Both cases included shading blinds, where in the case of double skin they were placed in the cavity, and for double glazing on the interior of the building.

Monthly heating and cooling loads were calculated according to the environmental conditions. Primary conclusion of the study is that for all climate types there is an increase on the performance of the double skin façade compared to single skin, but percentage and ways for improved performance differ according to location. In hot and warm climates, primary advantage is that during cooling season double skin permits less solar energy into the building, thus reducing energy consumption for cooling. In cold and temperate climates, comparison between double and single skin reveals that primary advantage is during the heating season.

Since the behavior of double skin facades is highly dependent on the type of climate, following sections outline a process for selecting the type, analyzing characteristics and properties and selecting strategies preferable for a specific context.

3.0 DESIGN REQUIREMENTS

The primary design objective for any building envelope is to sustain conditions of thermal, visual and acoustic comfort with minimum energy consumption[6]. Thus, controlling physical environmental factors (heat, light, sounds) must be considered during the design process. Currently, there are not widely-adopted guidelines for the design of double skin walls, but rather selected sources for best practices[1,7]. Typically, criteria that apply to single skin facades also apply to double skin facades, therefore this section outlines parameters for thermal, visual and acoustic comfort with respect to local environmental conditions. Variables that affect the performance of double skin façade include:

External Environment:
- Air temperature
- Solar radiation
- Humidity
- Wind velocity
- Illumination level
- Noise

Site:
- Dimensions and orientation of external obstacles (buildings, topography, landscape)
- Solar radiation reflectivity and light of surrounding surfaces

Building:
- Orientation
- Use/function
- Form
- Type of ventilation
- Thermal and energy loads

Space:
- Position within the building
- Dimensions and shape
- Orientation

Building Envelope:
- Material properties (type, thickness, density, conduction, light absorption)
- Glazing (type, number of layers, heat transmission, absorption, reflection)
- Air cavity dimensions
- Envelope type (single story, multiple story)
- Ventilation mode (natural, mechanical, hybrid)
- Air flow type
- Shading

Geometry, type, ventilation mode and system components are dependant on the location and crucial characteristics are temperature and air flow inside the cavity. Properties that influence air temperature and flow are cavity depth, glazing type, position and type of shading devices, ventilation strategy as well as size and position of inlet and outlet openings of the cavity. Comparative analysis and simulation of changing these parameters can provide useful information for façade behavior and assist in optimizing the façade function and operation.

Conditions of the external environment, building orientation, space dimensions as well as internal environment should be considered. For example, air temperature, solar radiation, humidity, wind velocity, noise, dimensions are orientation of external obstacles (buildings, topography, landscape), ground reflectivity are parameters that affect thermal, visual and acoustic comfort. In selecting building envelope type, decisions must be made for material properties (type, thickness, density, conduction, light absorption), glazing type (thickness, number of layers, heat transmission, absorption, reflection), air cavity and ventilation type (natural, hybrid, mechanical), envelope type (single floor, multiple floor), location and orientation of air intake and exhaust (inside to inside, inside to outside, outside to inside, outside to outside) and provision of shading.

Figure 2 presents selection process for the double skin façade that addresses thermal, visual and acoustic comfort. It is important to note that the other types of performance measures can also be incorporated, such as energy usage, indoor air quality, maintenance costs, etc. The basic process is that environmental conditions, building and room properties as well as performance specifications are utilized to select building envelope alternatives. If the selected building envelope does not meet the criteria, process is repeated until appropriate envelope alternatives are determined. Table 1 outlines types of parameters affecting thermal, visual and acoustic comfort.

Building performance requirements for double skin facades consist of measures for physical behavior, energy performance and thermal comfort, acoustic performance, fire protection, visual comfort, etc. As it is shown in Table 1, location specific characteristics affect thermal and visual comfort, therefore in developing strategies that are context-based, these aspects should be considered. Control strategies that allow the use of solar gains during the heating period and provide acceptable comfort conditions during the entire year are acceptable for temperate and cold climates and may be adapted for hot and arid. Energy consumption is closely related to thermal and visual comfort and in the following section is utilized as a measure for selecting design strategies applicable for particular climate types.

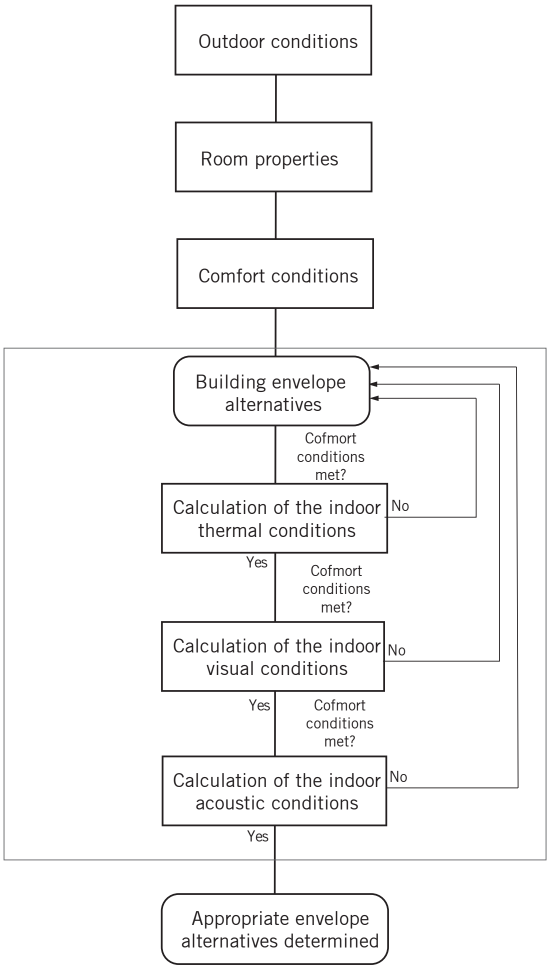


Figure 2: Selection process for building envelope design (Adapted from Oral et al., 2004).

4.0 ENERGY PERFORMANCE OF DOUBLE SKIN WALLS

During the planning and design process, recommendations for the design of double skin walls are to select appropriate control strategy for ventilation air cavity, select glazing properties as well as to plan for provision of shading devices. Since these choices are greatly dependent on the building location, function and climate, predicting energy performance early in the design stages can influence design decisions. In analyzing appropriate design strategies that are dependent on the climate and location, comparison of energy consumption for single skin and double skin façade is a viable option. Moreover, selection of design strategies can be improved if design options are investigated based on the energy consumption. The following sections illustrate the process for hot and arid and cold climate with warm summer.

4.1 Double Skin Wall for Hot and Arid Climate

Highly glazed facades are the major concern for energy consumption in hot and arid climates[8]. Traditional techniques for control of microclimates within this type of environment include preferential glazing to admit or block insulation, appropriate location and orientation of spaces to introduce air currents within inhabited spaces, employment of passive strategies (ducts, wind towers and shafts) to promote circulation as well as heat extraction through evaporative cooling.

Past research on design strategies and performance of double skin walls in hot and arid climate are extremely limited[9]. One of the few studies that specifically focused on comparison between single skin and double skin walls in this type of climate found that single skin façades account up to 45 percent of the building's cool-

Table 1: Comfort and design parameters for heat, light and sound comfort for double skin walls.

Conditions	Thermal Comfort	Visual Comfort	Acoustical Comfort
Indoor comfort parameters	Air temperature Relative humidity Air velocity Mean radiant temperature	Illuminance level and distribution Glare index	Acceptable noise levels
Outdoor design parameters	Obstruction properties Building dimensions Air temperature Relative humidity Wind velocity Solar radiation	Obstruction properties Building dimensions Latitude and location Day, hour External horizontal illuminance Ground properties	Obstruction properties Building dimensions Noise level Noise source
Indoor design parameters	Space dimensions User's activity level User's clothing insulation	Space dimensions Color of surfaces Working plane location	Space dimensions Internal surfaces absorption coefficients
Building Envelope Properties			
Glazing	Orientation Number of layers Layer thickness Overall heat transfer coefficient Shading factor Glass transmittance for direct and diffuse solar radiation	Orientation Window properties, location and shape Glass thickness Glass reflectance	Transparency ratio Number of layers Layer thickness Layer density
Air cavity	Orientation Number of layers Layer thickness Heat transfer coefficient of layers Density and specific heat of the layers Vapor resistance of the inner layers of wall construction Absorptance coefficient of the external surfaces of opaque components Ventilation type	Dimensions Glazing location	Dimensions Materials

ing load and that with careful material selection double skin walls result in substantial decrease in peak and annual cooling loads. The type of analyzed double skin is multi-story external air curtain with 1 meter cavity continuously occupying five stories. Results indicate that clear glazing for double skin walls increases energy consumption compared to single skin. However, tinted and reflective glazing significantly lower energy consumption. This study did not analyze low-e coatings, integration of shading devices, effects of changing dimensions of the air cavity or hybrid ventilation system.

In order to study effects of changing design parameters, such as air cavity dimensions, type of glazing, effect of shading and overhang, different design scenarios were investigated for a double skin wall shown in Figures 3 and 4. Two single skin base models were chosen—double-glazed and triple-glazed. For the double skin façade, several scenarios were investigated with changing design variables, such as air cavity depth, type of glazing and overhang dimensions. The type of double skin wall was multi-story with hybrid ventilation system and exhaust air flow type.

Static variables for all double skin scenarios were location and weather data, occupancy and equipment loads, air change rate, lighting control as well as dimensions and orientation, as seen in Table 2. Several different scenarios for double skin wall were investigated where properties were varied in order to compare effects of different design elements on energy performance. Dynamic variables included glazing type, window area, overhang dimensions and air cavity depth, as shown in Table 3.

Results show that any type of double skin wall performs better than the two base models for single skin double glazed and triple glazed façade (Tables 4 and 5). Table 4 compares effects of changing air cavity depth and type of glazing. It is indicated that smaller cavity results in lower energy demand since reduction in cavity size increases air pressure and induces air flow. High performance glazing would result in a slight decrease in energy demand compared to low-e glazing.

It is evident that scenarios with the lowest energy demand have smaller air cavity depth and reduced window area. By lowering the effective window area, significant reductions in energy consumption are observed, as seen in Table 5. Also, reduction of the deep roof overhang does not greatly increase cooling loads.

Figure 5 compares the single skin and double skin and advantages of the double skin wall are primarily present during winter months since it insulates and traps heat. During summer months, performance of double skin wall is comparable to the single skin. Compared to double-glazed single skin, almost all types of double skin wall would minimize cooling loads. Triple-glazed single skin would only perform better than double skin during the month of August. Best candidate for the overall reduction is double skin with smaller cavity depth and low-e or high-performance glazing. Reduction in effective window area would decrease energy demand, particularly during hot summer months, as shown in Figure 6.

Based on these results, recommendations for design of double skin facades in hot and arid climates are:

- Air cavity: Limiting the air cavity size reduces cooling loads.
- Airflow types: Since majority of consumed energy is utilized for cooling, there are possible advantages for hybrid ventilation type. Hot and arid climate has strong temperature shifts and that could be used as an advantage. For example, in the wintertime, double skin traps heat, thus providing an insulating layer. Diurnal change between hot day temperatures and cold night temperatures could also be used, where mechanical system could be used during the day and natural ventilation during the night. During hot days, mechanical system should be used to ventilate the air cavity.

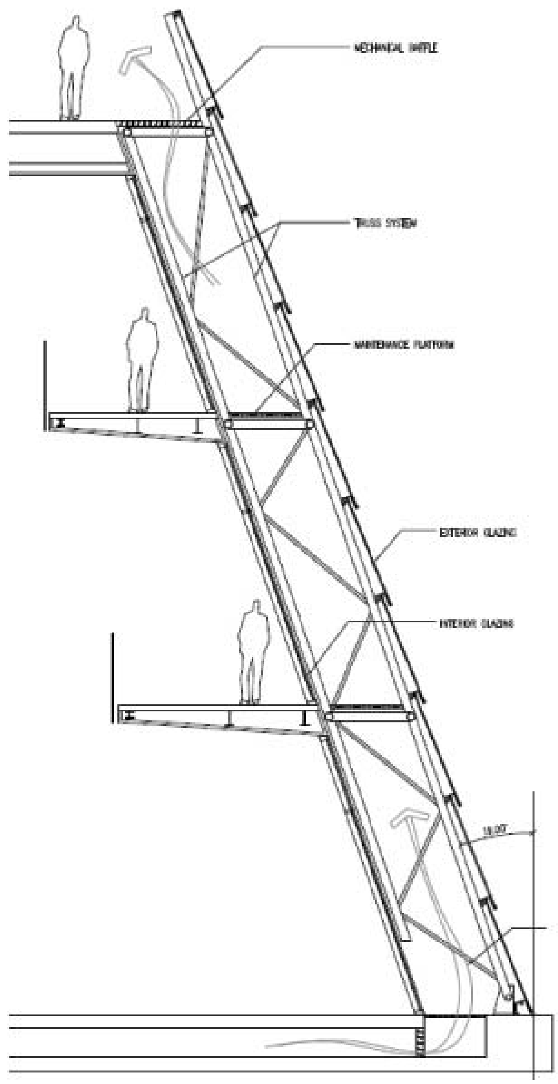


Figure 3: Double skin wall, hot and arid climate.

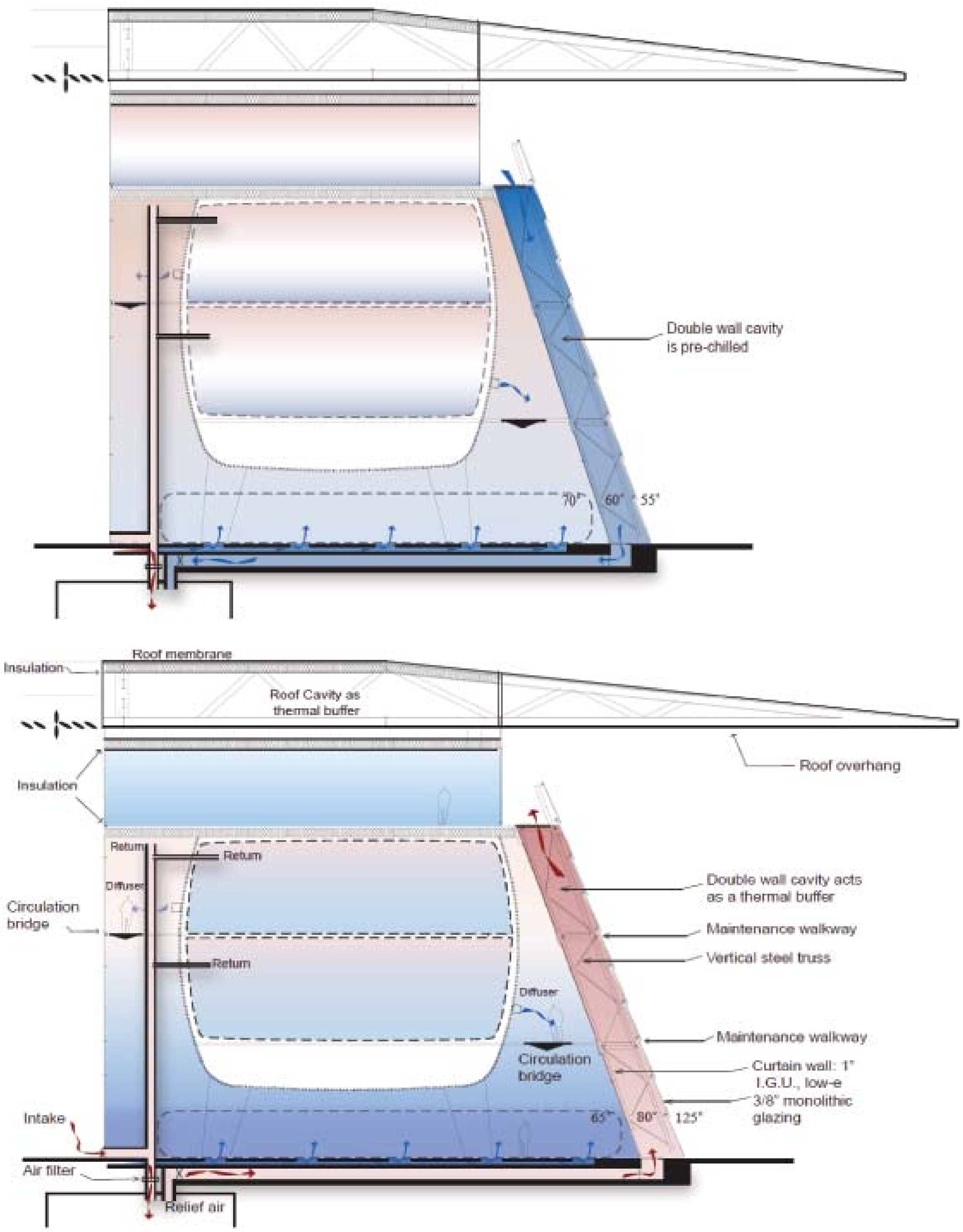


Figure 4: Components and ventilation mode of the double skin wall for hot and arid climate.

Table 2: Static variables for all façade types.

All Facade Types	
Location	Abu Dhabi, UAE
Orientation	SW
Temperature Min	20°C
Temperature Max	26°C
Humidity Max	60%
Occupancy	7 am to 5 pm
Occupancy load	0.25 people/m2
Lighting requirements	200 lux
Equipment load	1.00 W/m2
Air change rate per occupant	15.0 l/s per person
Total air change rate	0.9 roomful per hour
Dimensions	
Depth	26 m
Width	110 m
Height	15.6 m
Thermal mass	low

Double Skin Facade	
Type	Multi-storey
Ventilation mode	Hybrid
Air flow type	Exhaust air (interior vent supply, exterior vent exhaust)
Flow rate	50 m3/hr
Shading	Blinds that respond to temperature, located within the air cavity
Location of double glazing	In

Table 3: Dynamic variables for façade types.

	Window area	Glazing Type	Air Cavity	Overhang
Base model 1	80%	Low-e (double glazing, air)	None	15 m
Base model 2	80%	Low-e (triple glazing, air)	None	15 m
Scenario 1	80%	Low-e	1 m	15 m
Scenario 2	80%	Low-e	1.5 m	15 m
Scenario 3	80%	High-performance	1 m	15 m
Scenario 1.1	50%	Low-e	1 m	10 m
Scenario 1.2	80%	Low-e	1 m	10 m
Scenario 1.3	80%	High-performance	1 m	14 m
Scenario 2.1	50%	Low-e	1.5 m	14 m

Table 4: Annual energy consumption by façade type.

	Base Model 1	Base Model 2	Scenario 1 (1 m cavity, low-e glazing)	Scenario 2 (1.5 m cavity, low-e glazing)	Scenario 3 (1 m cavity, high performance glazing)
January	16.3	15.7	8.5	11.1	8.1
February	13.9	13.4	7.7	10.1	7.3
March	19.8	19	13.1	15	12.7
April	25.4	24.6	20.9	22	20.5
May	33.4	32.2	30.2	31.3	29.7
June	41.9	40.6	39.6	40.7	39
July	52.1	50.4	50.5	51.8	49.9
August	60.9	59.1	60.6	61.9	60
September	51.5	49.8	47.8	48.9	47.2
October	42.2	40.7	34.2	35.5	33.6
November	29.8	28.8	21.4	22.7	21
December	20.7	19.9	12.7	14.8	12.3
Total Energy (kWh/m2)	**407.9**	**394.2**	**347.2**	**365.8**	**341.3**

Table 5: Effect of dynamic variables on energy demand.

	Scenario 1.1 (1.0 m cavity, low-e glazing, 50% window area, 10 m overhang)	Scenario 1.2 (1.0 m cavity, low-e glazing, 80% window area, 10 m overhang	Scenario 1.3 (1.0 m cavity, high-performance glazing, 80% window area, 14 m overhang)	Scenario 2.1 (1.5 m cavity, low-e glazing, 50% window area, 14 m overhang)
January	7.3	8.7	8.2	7.2
February	6.7	8.1	7.3	6.5
March	12.2	13.7	12.8	11.8
April	19.6	21.5	20.5	19.3
May	28.3	30.6	29.7	28.1
June	37	39.9	39	36.8
July	47.2	50.9	49.9	47.1
August	57.6	61.2	60.1	57.3
September	45.2	48.6	47.3	44.8
October	31.9	34.7	33.7	31.6
November	19.8	21.7	21	19.7
December	11.4	12.9	12.3	11.3
Total Energy (kWh/m2)	**324.2**	**352.5**	**341.8**	**321.5**

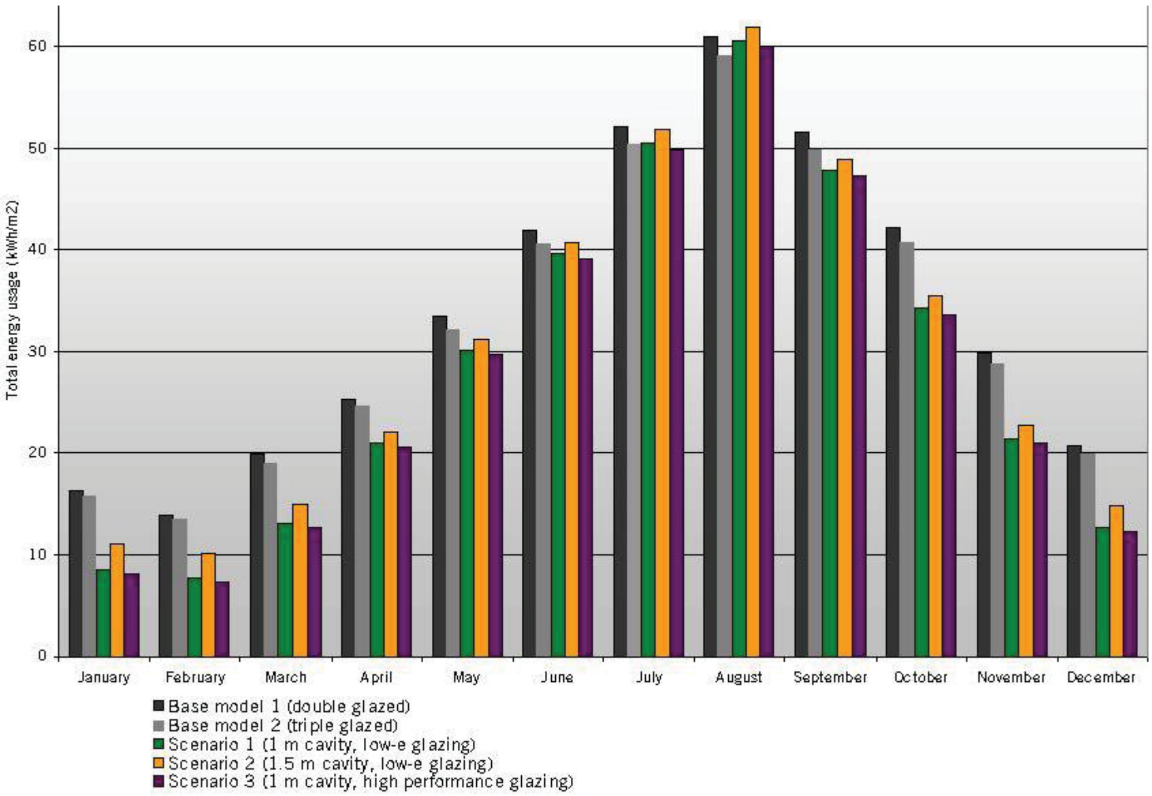


Figure 5: Annual energy demand for single skin and double skin types for hot and arid climate.

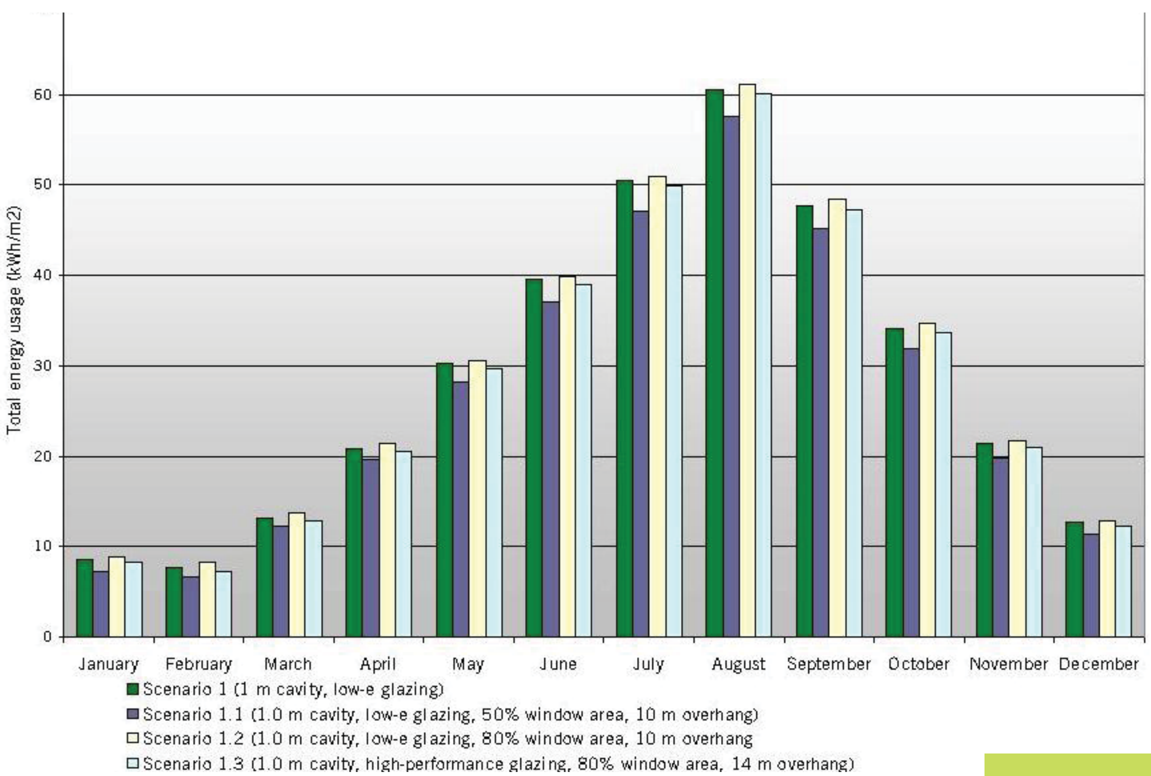


Figure 6: Effect of changing design variables of double skin wall on annual energy demand.

- Shading: Roof overhangs provides some protection against solar heat gain, but incorporation of shading devices within the air cavity is also important, located closer to the external skin.
- Glazing: Effective window size and glazing types have a significant impact on energy consumption. Minimizing window size and selecting low-e or insulating glazing can decrease cooling loads during hot summer months.

4.2 Double Skin Wall for Cold Climate

There has been significant past research on performance of double skin walls in temperate and cold climates[10,11]. For this type of climate, the main advantage is improved thermal insulation. During the winter months, exterior skin increases external heat transfer resistance, therefore utilizing interior air for preheating air cavity is advantageous. During the summer, air must be extracted in order not to cause overheating, by natural, hybrid or mechanical modes.

Critical factors for double skin walls in temperate and cold climates are geometry of the air cavity, type of ventilation system and air flow mode. Poizaris claims that the most important parameters in designing the double skin façade in this type of climate are dimensions of the air cavity (width and height), since they have the greatest influence on heat and flow performance. Lee et al. claim that proper ventilation of the cavity is highly dependant on the combination of the glass panes, ventilation mode as well as size of the air cavity[12].

In order to investigate effects of these design parameters on energy consumption, such as air cavity dimensions, location of double skin as well as difference in operation during winter and summer months, different scenarios were investigated for a multi-story double skin wall shown in Figure 7. In order to study the effects of changing air cavity geometry, location of double skin as well as different air flow types, different design scenarios were investigated.

Static parameters for all façade types are shown in Table 6. Changing properties are shown in Table 7. Base model included double-glazed single skin façade with low-e glazing. For double skin façade, location of double glazing was varied from the internal to external skin as well as cavity depth from 0.7 m to 1.4 m. Two different types of air flow were investigated—exhaust air during all year as well as combination of exhaust air during summer months and air curtain during winter months. This combined air flow type would allow utilization of warm air during winter to preheat the air cavity. All double skin scenarios include shading devices within the air cavity.

Results are shown in Figure 9. Base model (double-glazed single skin façade) has highest overall energy demand; however, looking at the annual energy demand reveals that some cases of double skin wall have higher heating loads during winter months (Figure 8). In particular, air flow type has a major effect, since exhaust air type increases heating demand. Results indicate that trapping air within the air cavity during winter months insulates the double wall, thus significantly lowering heating loads.

Air cavity size does have an effect on energy consumption; however, more important is the location of the double glazing. Results show that exterior placement of double glazing would significantly reduce energy consumption, compared to placement on the interior skin. Size of air cavity also has an effect, where cavity with a small opening can negatively influence stack effect. Also, air cavities that are too large increase the cost.

Combination that performs well for all seasons has average air cavity size, location of the double-glazing. Based on the performed parametric energy analysis for several possible design scenarios, it is concluded that the best possible candidate would contain double glazing on the exterior and single glazing on the interior side. Interior to interior air flow would perform better based on the results, but it is recommended to consider combined interior to interior and interior to exterior air exchange, where interior to interior would be utilized in winter to reduce heating load and interior to exterior in summer to reduce cooling load.

Based on these results, recommendations for design of double skin walls in cold climates are:

- Air cavity: Air cavity that is too small does not perform well for natural ventilation, but the size should be balanced with other considerations, such as cost and operation and maintenance.
- Airflow types: Primary concern is heating demand, but balance between heating and cooling loads is essential for this type of climate. Since large portion of consumed energy is utilized for heating, there are advantages for utilizing trapped air to improve insulation and heat transfer between the exterior and interior environment. During summer months, air cavity must be ventilated to protect from overheating.
- Glazing: Location of double glazing can improve overall energy consumption and placement on the

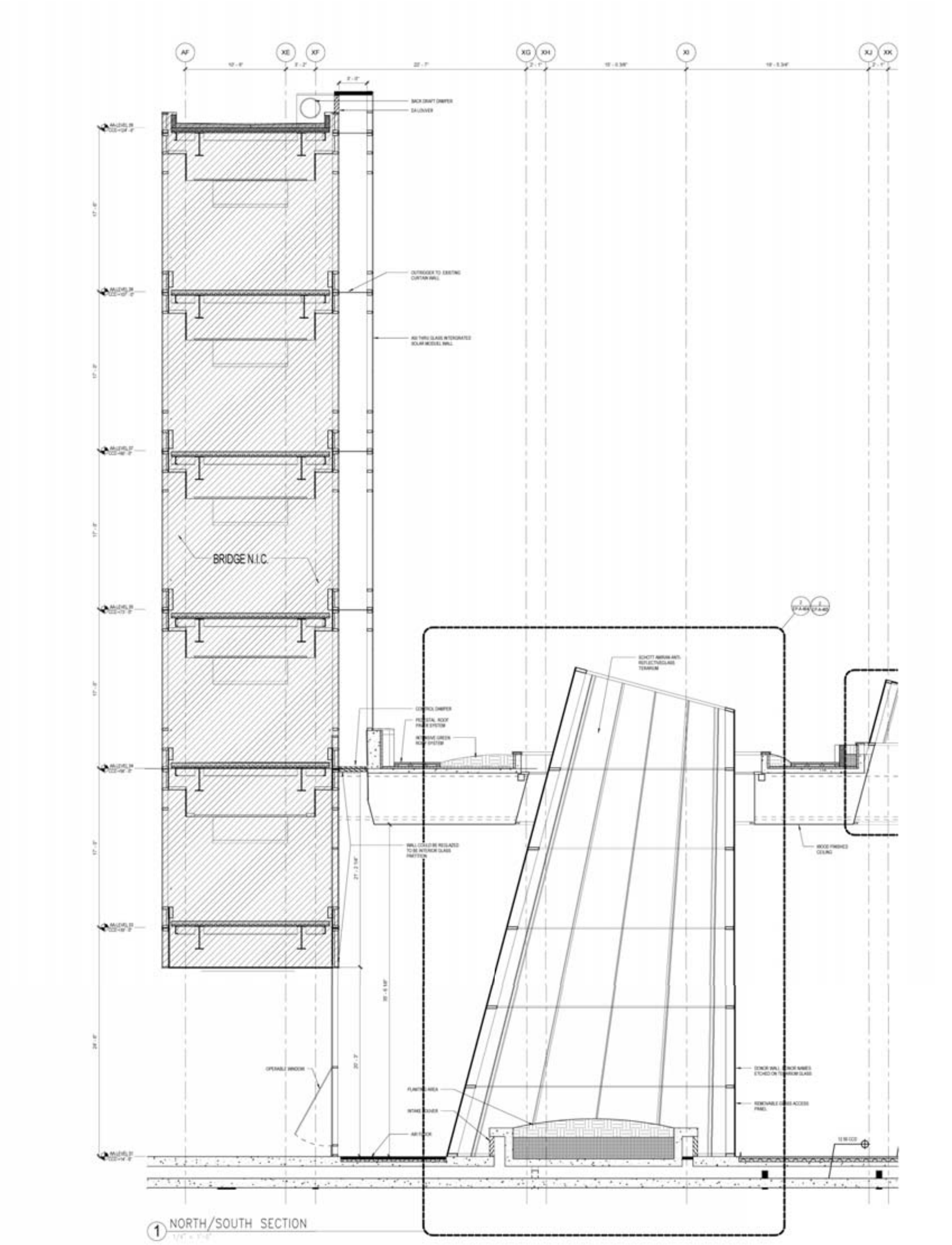


Figure 7: Double skin wall, cold climate.

Table 6: Static variables for all façade types.

All Facade Types	
Location	Chicago, IL
Orientation	S
Temperature Min	20°C
Temperature Max	26°C
Humidity Max	60%
Occupancy	7 am to 9 pm
Occupancy load	0.25 people/m2
Lighting requirements	200 lux
Equipment load	1.00 W/m2
Air change rate per occupant	15.0 l/s per person
Total air change rate	0.9 roomful per hour
Dimensions	
Depth	5.5 m
Width	21.3 m
Height	18.9 m
Glazing type	low-e
Window area	80%
Thermal mass	low
Double Skin Facade	
Type	Multi-storey
Ventilation mode	Hybrid (natural, assisted by mechanical)
Flow rate	50 m3/hr
Shading	Blinds that respond to temperature, located within the air cavity

Table 7: Dynamic variables for façade types.

	Location of Double Glazing	Air Flow Type	Air Cavity
Base model	-	-	-
Scenario 1	In	Exhaust air (interior vent supply, exterior vent exhaust)	0.5 m
Scenario 2	In	Exhaust air (interior vent supply, exterior vent exhaust)	0.7 m
Scenario 3	In	Exhaust air (interior vent supply, exterior vent exhaust)	1.0 m
Scenario 4	In	Exhaust air (interior vent supply, exterior vent exhaust)	1.4 m
Scenario 2.1	Out	Exhaust air (interior vent supply, exterior vent exhaust)	0.7 m
Scenario 3.1	Out	Combination (exhaust air summer, air curtain winter)	1 m
Scenario 2.1.1	Out	Combination (exhaust air summer, air curtain winter)	0.7 m
Scenario 3.1.1	Out	Combination (exhaust air summer, air curtain winter)	1.0 m

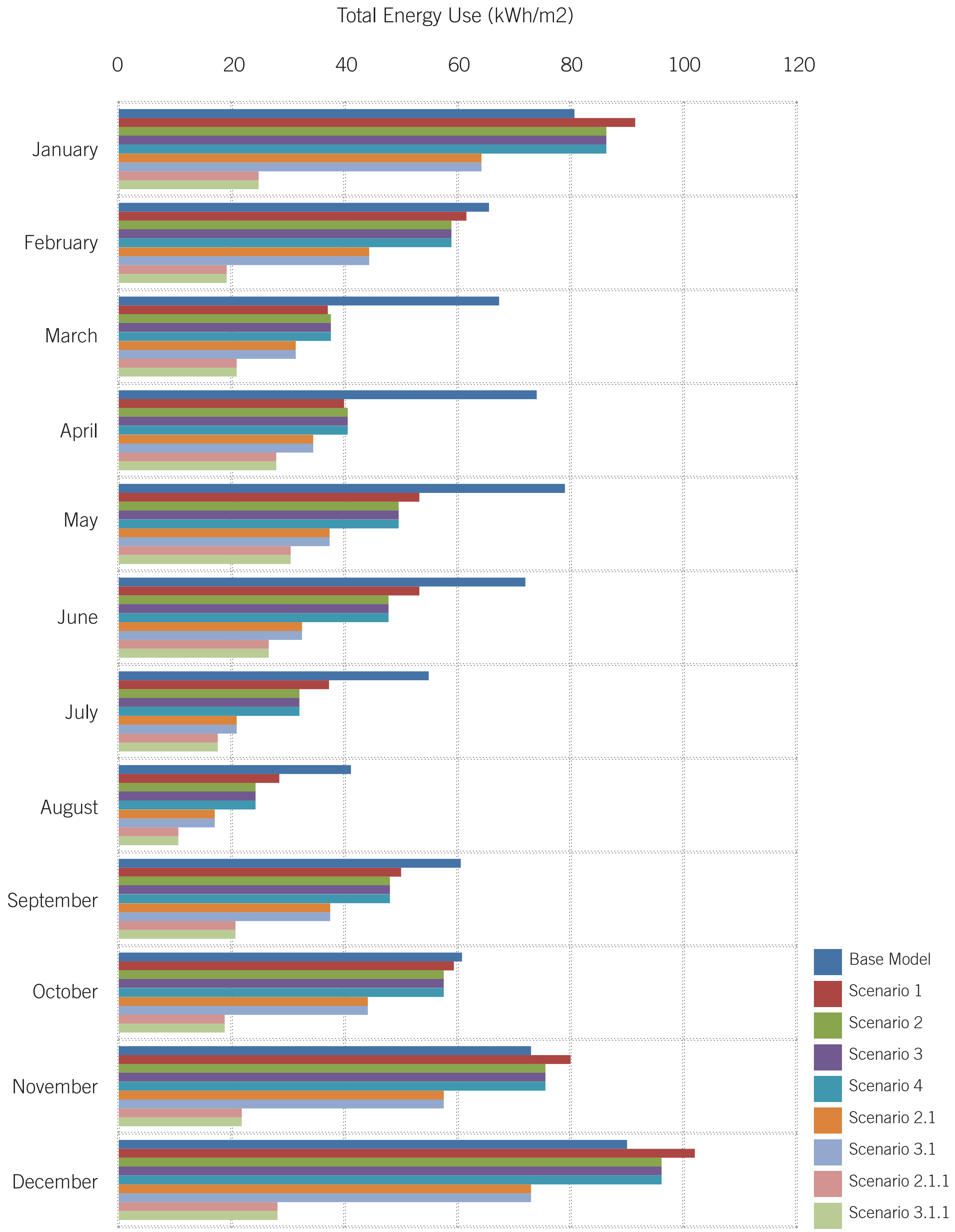


Figure 8: Annual energy demand for single skin and double skin types for cold climate.

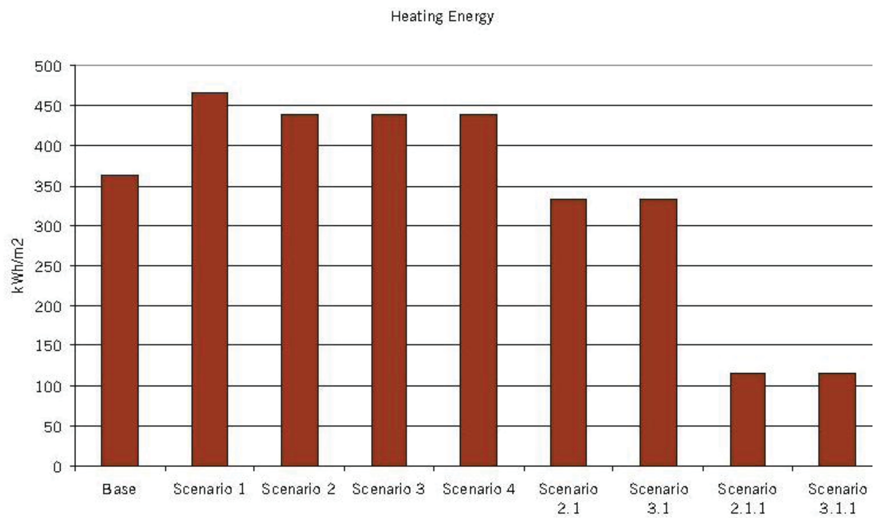


Figure 9: Heating energy.

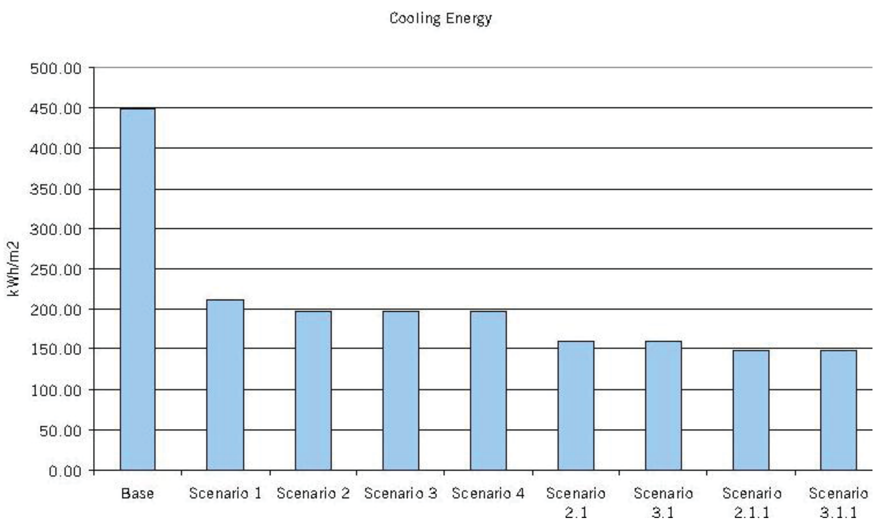


Figure 10: Cooling energy.

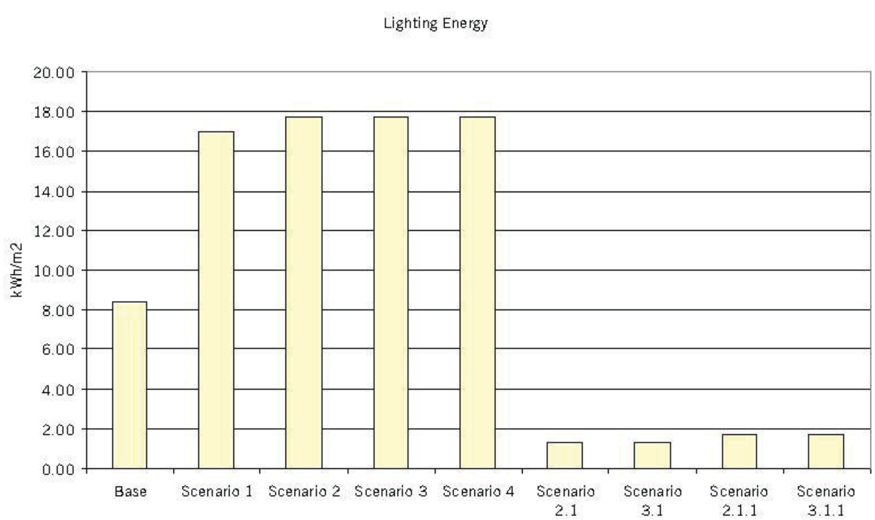


Figure 11: Lighting energy.

exterior skin improves heating, cooling and lighting energy consumption.

5.0 CONCLUSION

Design objectives for any façade type are to provide thermal, visual and acoustic comfort with minimum energy consumption. Basic considerations for the design of double skin wall include geometry, type, ventilation mode and air flow. Since there are numerous combinations between different types, ventilation strategies as well as components, context-based design that adapts to local environmental conditions is of primary importance.

Comparative analysis and simulation of changing these parameters can provide useful information for façade behavior and assist in optimizing the façade function and operation. In this article, energy consumption is analyzed for double skin walls in two distinct types of climates, where energy consumption is compared for different design scenarios.

Design strategies for double skin walls should reflect the climatic conditions and for hot and arid climates reduction of cooling loads is the primary concern, while for temperate and cold climates reduction in heating loads as well as balance with summer cooling load. Based on the results of this study, design strategies for hot and arid climate that minimize energy consumption include reduction in size of air cavity, adapting ventilation modes and airflow types to seasonal and daily temperature changes, providing shading devices and deep roof overhangs, reducing effective window size as well as selecting glazing types that decrease cooling loads. For cold climates, primary concern is the heating demand and there are advantages in changing the air flow mode according to different seasons. In winter, there are advantages in utilizing trapped air to improve insulation and heat transfer between the exterior and interior. In summer, ventilation of air cavity is essential for reducing cooling loads. Location of double glazing on the exterior skin improves the overall energy consumption.

REFERENCES

[1] Blomsteberg, A., ed. (2007). BESTFAÇADE: Best Practices for Double Skin Facades, EIE/04/135/S07.

[2] Badinelli, G., (2009). “Double Skin Facades for Warm Climate Regions: Analysis of a Solution with an Integrated Movable Shading System”, Building and Environment, Vol. 44, pp. 1107-1118.

[3] Tanaka, H., Okumiya, M., Tanaka. H., Yoon, G., and Watanabe, K., (2009). “Thermal Characteristics of a Double-Glazed External Wall System with Roll Screen in Cooling Season”, Building and Environment, Vol. 44, pp. 1509-1516.

[4] Haase, M., Marques da Silva, F., and Amato, A., (2009). “Simulation of Ventilated Facades in Hot and Humid Climates”, Energy and Buildings, Vol. 41, No. 4, pp. 361-373.

[5] Zerefos, S., (2007). “On the Performance of Double Skin Facades in Different Environmental Conditions”, International Journal of Sustainable Energy, Vol. 24, No. 4, pp. 221-229.

[6] Oral, G. K., Yener, A. K., Bayazit, N. T., (2004). “Building Envelope Design with the Objective to Ensure Thermal, Visual and Acoustic Conditions”, Building and Environment, Vol. 39, pp. 281-287.

[7] Poirazis, H., (2006). Double Skin Facades: A Literature Review, IEA SHC Task 34 ECBCS Annex 34 Report, Lund: Lund Institute of Technology.

[8] Askar, H., Probert, S. D., and Batty, W. J., (2001). “Windows for Buildings in Hot Arid Countries”, Applied Energy, Vol. 70, pp. 77-101.

[9] Hamza, N., (2008). “Double versus Single Skin Facades in Hot Arid Areas”, Building and Environment, Vol. 40, pp. 240-248.

[10] Stec, W. J., and van Paaseen, A. H. C., (2005). “Symbiosis of the Double Skin Façade with the HVAC System”, Energy and Buildings, Vol. 37, No. 5, pp. 461-469.

[11] Lee, E., Selkowitz, S., Bazjanac, V., Inkaroirit, V., and Kohler, C., (2002). “Higher-Performance Commercial Building Facades”, LBNL-50502 Report, Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory.

06.
MOUNTAIN PINE BEETLE
The Potential Carbon Emissions of Harvesting Dead Lodgepole Pine

Chessa A. Adsit-Morris, LEED® AP, *chessa.adsit-morris@busbyperkinswill.ca*

ABSTRACT
This report accesses the potential carbon emissions of harvesting dead lodgepole pine as a result of an outbreak of mountain pine beetles. The report reviews the potential benefits (pros) and the many concerns (cons) about the harvesting practices and strategies utilized to mitigate the socio-economic and carbon emission impacts of mountain pine beetle outbreak. The goal is to help designers better understand the potential implications of specifying wood products. Could current harvesting practices emit more carbon than is estimated to be released by the dead and decaying trees?

DEFINITIONS:
Allowable Annual Cuts (AAC) - The rate at which timber is made available for harvesting in response to social, economic and environmental considerations. The AAC is determined either by the Chief Forester in British Columbia or by forest managers for individual Forest Management Units (FMUs), in partnership with provincial government.
Afforestation – The process of establishing a forest on land that is not a forest or has not been a forest for a long time.
Biomass (ecology) – The mass of living biological organisms in a given area or ecosystem at a given time. Biomass can refer to a single species, which is the mass of one or more species, or to a community, which is the mass of all species in the community including microorganisms, plants and animals.
Bycatch – Species of trees cut down during a clear-cut that is not the intended or sought-after species.
Early successional species – Species that are fast-growing, well dispersed, opportunist species (r-selected species). As succession proceeds, these species are replaced by more competitive, shade tolerant (k-selected) species.
Girdling – Also called ring barking, is the process of completely removing a strip of bark, including the phloem, cork cambium and cork, around a tree's outer circumference, cutting off it's flow of water and nutrients. Girdling is used as a silvicultural practices to thin a forest stand, by accident or by herbivores who feed on bark.
Mountain pine beetle – Dendroctonus ponderosae, a species of bark beetle native to the forests of western North America from Mexico to central British Columbia.
Pheromone baiting – The practice of using pheromone (semiochemical) baits to manipulate the behavior of bark beetles by attracting and concentrating new attacks to baited trees that can be managed and removes easier.
Phloem - The innermost layer of bark which transports nutrients, specifically sucrose, from the leaves to other parts of the tree.
Pupae – A life cycle stage for holometabolous insects that undergo a complete metamorphosis of four stages of life: embryo, larva, pupa and imago. The pupal stage follows the larval stage and proceeds adulthood or imago.
Secondary structure
Silviculture – The science (and art) of controlling the growth, establishment, composition, health and quality of a forest to meet management goals. Silvicultural practices will vary depending the management goals and objectives (i.e. productions of wood vs. habitat quality)

Skip and skid – These are two methods used for primary transport of felled logs from their original point of extraction (or felling) to a landing or processing location. Skidding is the movement of felled trees or logs to a landing or processing location by dragging on the ground by an animal (mule or oxen) or mechanically with a rubber-tired skidder or tracked skidder.
Succession – Refers to (more-or-less) predicable and orderly changes in the structure and composition of an ecosystem after a disturbance such as a fire.
Understory – The term for the area of a forest which grows in the shade of the forest canopy. This includes seedlings, saplings, shrubs and herbs.

1.0 INTRODUCTION

This report accesses the potential carbon emissions of harvesting dead lodgepole pine as a result of an outbreak of mountain pine beetles. The current mountain pine beetle attack began in 1997 and is estimated to have peaked in the summer of 2004 affecting 13.5 million hectares or 141 million cubic metres of pine (British Columbia Ministry of Forestry). The current attack is ten times larger than any known historical attack. The largest previous outbreak occurred between 1930 and 1936 and peaked at 650,000 hectares. The outbreak of the pine beetle infestation has caused British Columbia's forests to become a carbon source instead of a carbon sink. Researchers from the Canadian Forest Service report that an extra 990 million tonnes of carbon dioxide, or 270 million tonnes of carbon will be emitted into the atmosphere, which is equivalent to five times the annual emissions from all the cars, trains and planes in Canada. However, could current harvesting practices emit more carbon than is estimated to be released by the dead and decaying trees?

There are a number of other environmental issues associated with the harvesting and use of dead lodgepole pine that are not addressed in this report such as habitat loss, erosion of topsoil, impacts to the natural hydrological cycle or socio-economic impacts. Natural disturbances such as pine beetle attacks play an important role in maintaining ecosystem processes. Natural disturbances create diversity on spatial and temporal scales, which are important for forest health, productivity and biodiversity[1]. The fact that we are not addressing these issues in this report should not reflect negatively upon the importance of these issues.

1.1 Climate Change

The main increases in atmospheric levels of carbon dioxide are attributed to the burning of fossil fuel and land use change, specifically deforestation. The reduction of carbon dioxide emissions from fossil fuel use is of major concern and must be addressed however, emissions can also be offset, to a degree, by accumulation in carbon sinks such as plant biomass and oceans. Key individual GHG mitigation options in the U.S. and Canadian forest industry include:

- Afforestation
- Sustainable forest management, (i.e. thinning, removing dead wood or planting trees to fill in an under-stocked stand)
- Forest preservation
- Fertilization, improved stocking, species mix and extended rotations
- Modified harvesting practices (extending average life of trees until mature)
- Fire suppression and management
- Increase use of wood products, (i.e. substitute wood for concrete/steel)
- Extended wood product life
- Recycle wood and paper products

Sequestration of carbon dioxide in plant biomass and oceans as well as capturing carbon dioxide in carbon stores such as wood products does not offer the ultimate solution towards stabilizing carbon dioxide concentrations, but if part of a broader package of options, with clear energy emission reduction measures, can have a significant contribution.

Currently, the average service life of a wood framed house is 80 to 100 years and the construction industry uses nearly 47% of all softwood harvested, therefore the building industry can make a significant contribution to the reduction of carbon dioxide by specifying wood materials. The embedded energy of wood products compared to steel or concrete is significantly less. The Athena Institute completed a study showing that wood framed homes generated 26 to 31 percent less greenhouse gas emissions when compared to a steel and concrete framed house.

1.2 Lodgepole Pine

Approximately 141 million cubic meters of lodgepole pine has been affected by mountain pine beetle attacks throughout British Columbia (British Columbia Ministry of Forestry). The lodgepole pine grows throughout the northwest, has relatively thin bark and a shallow root system. Because the lodgepole pine has little taper and thin bark it produces a high volume of wood, which makes it ideal for the timber industry. Province wide lodgepole pine accounts for 25% of the timber supply annually and up to 80% in some central interior areas[1]. The lodgepole pine grows rapidly where competition is limited for about 60 years at which time maturity is reached. The pine beetle plays an important role in the lodgepole pine forest ecosystem by opening the canopy allowing needed sunlight to young lodgepole pine and thinning the forest allowing for diversity of species and age classes.

Lodgepole pines become susceptible to attack by mountain pine beetles when they reach at least 15 centimeters in diameter, which is typically at about 60 to 80 years of age[1]. At low populations pine beetles attack old and weak trees, which are more susceptible to attack. However, once the pine beetle populations become large and have increased beyond some critical threshold, pine beetles can successfully over power younger healthier trees. Currently over 2/3 of the lodgepole pine in B.C. forests are 60 years or older, which is one of the factors that has fuelled such a catastrophic outbreak.

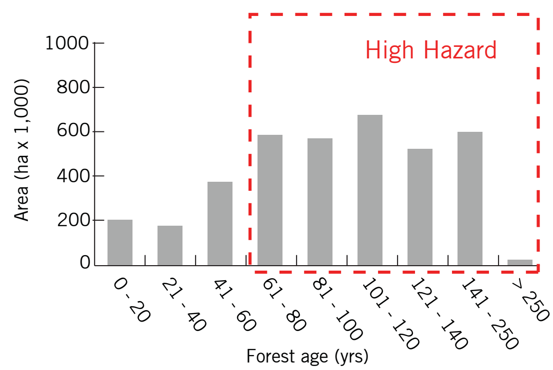


Figure 1: Age distribution of pine-dominated stands in B.C. (Adapted from Ref. [1])

The abundance of equal age lodgepole pine stands is due to widespread fires in the late 1800s and early 1900s during the European settlement. The settlers' slash and burn techniques were ideal for the lodgepole pine due to it being an early successional species. Fire suppression policies and practices during the 1970s, used to save timber stocks, also helped to create continuous stands of even-aged stands. The British Columbia Ministry of Forests and Range estimate that currently British Columbia has three times more mature lodgepole pine than it did 90 years ago. The second factor contributing to the magnitude of the current outbreak is climate change. Under normal conditions pine beetle populations are kept in control by freezing temperatures. Temperatures below -35 degrees Celsius for several days will kill off large numbers of pine beetle eggs and pupae. The warming temperatures during the winter and dry summers have been ideal for pine beetle populations. Additionally, these hot and dry summers drought-stress the trees leaving them weak and more susceptible to attacks by the mountain pine beetle.

1.3 The Mountain Pine Beetle (D. ponderosa)

Lodgepole pine is extremely susceptible to mountain pine beetle attacks. The pine beetles attack in July or August by tunneling through the bark and lying eggs in the phloem. The beetles introduce blue stain fungi into the tree, which inhibits the tree's resin (sap) output, effectively disabling the tree's only defense mechanism as well as staining the wood blue. This allows the beetles to burrow under the bark without resistance from the tree. Once hatched, the beetle larvae feed on the bark, eventually causing girdling (removing a ring of bark which dissects the phloem and cork cambium, stopping the flow of nutrients and water throughout the tree) killing the tree. There are four factors that influence beetle populations: structure of stands, phloem thickness, moisture content and climate. Cold winters and forest fires usually function to keep the mountain pine beetle populations low.

1.4 Current Harvesting Practices

There are two types of harvesting for lodge pole pine; salvage harvesting, which refers to the logging of dead red and grey areas after beetle broods have passed through and sanitation harvesting, which refers to the logging of infected wood that house hibernating beetle larvae. Because beetle larvae overwinter in a tree and emerge as adults in the spring there is a chance that infected wood can be removed before the beetles emerge in the spring and attack new healthy trees. Currently, the British Columbia Chief Forester is allowing Annual Allowable Cut (AAC) uplifts to forests for "salvage" harvesting. Unfortunately, the Forest Practices of British Columbia Act does not distinguish between salvage logging and sanitation logging. Therefore, in forests where there are infected trees still hosting beetles, healthy trees are being harvested in addition to infected trees under the regime of "salvage" logging when clear-cut harvesting methods are used instead of selective harvesting or partial cuts. Additionally, other tree species are being harvested along with the dead and infected lodgepole pine. Currently, one or more non-pine species is being harvested for every two pine trees harvested during "salvage" logging[4].

2.0 POTENTIALS FOR HARVESTING SALVAGE WOOD

2.1 Carbon Stocks in Forests

Forests are the largest terrestrial reservoir for atmospheric carbon. Trees absorb carbon dioxide from the atmosphere through photosynthesis and use the carbon to build physical components such as branches, roots and leaves. Trees also release carbon dioxide through respiration, decomposition or when they burn. When a forest sequesters more carbon through photosynthesis than the release through respiration or decomposition it is considered to be 'carbon sink'. The current carbon stock in tree biomass comprises half of the atmospheric storage and is continuing to grow despite deforestation[8]. There are five storage pools in forests:

- Above ground biomass, which includes all living biomass above the soil including stem, stump, branches, bark, seeds and foliage. This category includes live understory.
- Below ground biomass, which includes all living biomass of coarse living roots greater than 2 mm diameter.
- Dead wood, which includes all non-living woody biomass either standing, lying on the ground or in the soil.
- Litter, which includes the litter, fumic and humic layers and all non-living biomass with a diameter less than 7.5 cm at transect intersection lying on the ground.
- Soil organic carbon (COC), including all organic material in soil to a depth of 1 meter, but excluding the coarse roots of the above ground pools[8].

Left entirely to nature, forests will achieve a climax stage, where the site is supporting the maximum amount of biomass that soil fertility, rainfall and temperature conditions will allow. At this point, the forest carbon capacity only grows as trees fall from age, wind, landslip, disease or fire. Not harvesting results in more onsite carbon storage than sequential harvest scenarios, regardless of rotation age, as shown in Figure 2.

Younger trees, in vigorous growth, absorb more carbon dioxide than mature trees, which will eventually die and

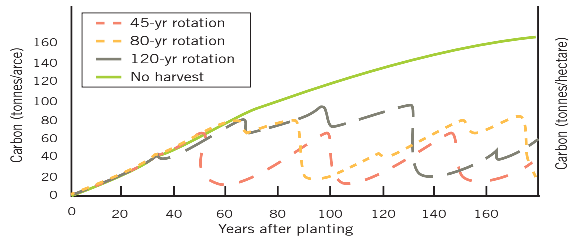


Figure 2: Carbon storage in the forest pool for 45, 80, 120 year rotations or harvest cycles and no harvest option that should be considered a potential maximum for carbon storage in the forest pool[7]. (Adapted from Ref. [7])

rot, returning their store of carbon dioxide to the atmosphere, while most of the carbon captured in the trees harvested from a managed forest will continue to be stored throughout the life of the resulting wood product. Additionally, a well managed forest has less soil disturbance and higher biodiversity, which also increases carbon stores (Possible management strategies are discussed in the conclusion). However, the largest source or sink of carbon in sub-boreal forests and most other forest types are found in old growth areas or stands[3]. Thus, proper management of young forests and protection of old growth forests is essential.

2.2 Harvesting of Dead Lodgepole Pine

Once a forest reaches its carbon sequestration (biomass) capacity, the carbon capacity of the forest can only be increased by removing and storing biomass. If sustainably harvested and 'stored' in wood products such as lumber or paper products, harvested wood can become carbon stores and help to optimize forest carbon sinks. Wood products are carbon stores, rather than carbon sinks, as they do not themselves capture carbon dioxide from the atmosphere, but they have an important role in enhancing the effectiveness of the forest sinks, both by extending the period that the carbon dioxide captured by the forests is kept out of the atmosphere and by encouraging increased forest growth by giving the industry an incentive to plant new trees in their place. There are two harvest wood product pools:

- Harvest wood products used in buildings and consumer products
- Harvest wood products in landfill

Increasing demand for wood as opposed to other building materials such as steel or concrete would also contribute to an increase or replanting of forests previously cut down for agricultural purposes (afforestation). Increasing the amount of forests will increase the global forest carbon sink and decrease the amount of carbon in the atmosphere. Currently, the biggest potential to increase carbon sequestration is in afforestation of marginal agricultural lands. In a report prepared for the Pew Center on Global Climate Change it estimated that conversion of an estimated 115 million acres of marginal agricultural lands in the Unites States to forests could sequester 270 million metric tons of carbon per year over a period of 100 years, which would offset nearly 20 percent of current emissions of carbon dioxide from US combustion of fossil fuels[5].

2.3 Harvesting Sanitation Wood

The selective harvest of infected pine beetle wood (sanitation wood) during the sanitation process could provide a number of benefits including the opportunity for younger pine trees in the understory to grow more rapidly and regenerate. The infected older adult lodgepole pines grow significantly slower than young lodgepole pines and therefore would not be sequestering as much carbon dioxide as a young growing tree. This provides an opportunity to replace the old and sick wood infested with beetle larvae with young trees, which would increase carbon sequestration capacity of the stand. Selective harvesting will also retain forest structure and prevent future out breaks because of the varied ages of trees.

3.0 CONCERNS AND DISCUSSION

3.1 Forest Fires

Carbon is 'captured' in wood until it is released either by burning (in wildfires or for energy) or by decomposition. An increase in the number of forest fires and higher-intensity forest fires due to the presence of dead wood, debris and hotter, dryer summers could potentially release stored carbon into atmosphere. For the first few years after a pine beetle attack while the dead lodgepole pine trees still retain their needles, the risk of forest fires increases. Once the dead lodgepole pine trees lose their needles the risk declines until the dead trees fall providing fuel for ground fires. One study of ponderosa pine forests in Idaho estimated that a high-intensity wildfire consumed an average of 79.5 metric tons of fuel and emitted approximately 132 metric tons of carbon dioxide per acre. Large areas of dead pine stands represent a potential fire hazard. The Province is directing fuel management activities in beetle areas to reduce threats to communities located in the infestation zone.

However, wildfires are essential for a healthy forest creating a patchy 'mosaic' landscape, increasing species diversity and quality of habitat. Lodgepole pines are an early successional species intolerant of shade and have serotinous (sealed by pitch) cones that do not open until they are heated by fire or direct sunlight. Thus, lodgepole pines will not regenerate under a closed canopy. Forest fires and other natural disturbances are essential to the reproduction and growth of lodgepole pine. Thinning of the forest by forest fires will increase young lodgepole growth by eliminating competition and opening up the canopy.

3.2 Allowable Annual Cut Uplifts

Forest companies, with approval from provincial regulatory agencies, have inserted AAC uplifts into their annual harvesting plan increasing the harvesting rate higher than long term sustainable harvest levels (as determined by the Chief Forester). The AAC for Quesnel TSA rose by 39% to 3.248 million cubic meters[1], a 50% increase in the 100 Mile House TSA[4], and a 103% increase in the Lakes TSA. The uplifts were set in place because the dead wood's economic value is believed to be degrading. However, the dead trees could stand for many years before beginning to breakdown and decompose. A study of stands killed by the mountain pine beetle in 1979, found that approximately half of the attacked trees were still standing and still sound 25 years after the attack[9]. Additionally, the stands were able to develop a unique multi-aged and size stand structure, which had considerable habitat value because it included elements of dead standing wood, fallen trees and a healthy understory. The study also found that the lodgepole pine trees able to withstand the attack (which generally ranged from 10 to 50%) grew significantly faster after the epidemic. The average increase according to this study was 44% greater[9].

AAC uplifts will have detrimental long-term effects on the forest ecosystems and the forest's capability to sequester carbon. AAC uplifts have been pushed by economic and community interests in order to mitigate the economic losses, however, AAC uplifts will also have a detrimental impact to the timber industry's economy during the re-growth of forests. After clear-cutting the replanted seedlings will take 60 or more years to reach harvesting age, yet if the forests are left to naturally regenerate the younger and smaller trees in the understory would be ready to harvest within 20-30 years, significantly less time, which will lessen the economic impact[4].

As noted in section 1.4, many mixed forests, forests with a high percentage of healthy trees and forests with high numbers of understory (non-pine) trees are being harvested under the guise of 'salvage' logging. The increase in AAC for salvage logging has also increased the harvesting of other species, (as 'bycatch') which would otherwise continue to sequester carbon until harvested in the midterm (30-40 years). Many of the forests affected by the mountain pine beetle are mixed forests with Douglas fir and true fir species. Roughly 39 percent of forests in British Columbia are comprised of forests that contain 90 to 100% pine. The other 60 percent are comprised of mixed forests dominated by other species. If the salvage harvesting efforts were focused only on the dead or infected lodgepole pine trees, other species of trees as well as healthy young lodgepole pine could be harvested in the midterm while the clear-cut salvaged forests are re-growing, softening the economic impacts. This would require using alternative harvesting methods such as partial cutting. In a report provided to the Chief Forester on the abundance of secondary structure in lodgepole pine stands affected by the mountain pine beetle concluded that only 20 to 25 percent of pine dominate stands lacked adequate secondary structure to regenerate without human intervention and were primate candidate for total salvage harvesting and replanting[6]. The report also stated that 20 – 30 percent of affected stands had sufficient understory to regenerate and the other 40 – 50 percent had other species that could provide midterm harvest opportunities.

3.3 Clear-cutting

The main method of harvesting used in British Columbia is clear-cutting in which most of the trees from an area are harvested leaving a large open area susceptible to erosion and loss of soil moisture due to increased temperatures. Environment Canada reports that clear-cutting is used for 99% of harvesting along the coast of BC and 90% in the Boreal Forests. Clear-cutting is the most efficient and safest harvesting method which also makes it the cheapest method as the cost of insurance for manual harvesting methods is 3 to 4 times higher. There is much concern that clear-cutting eliminates existing green and healthy trees of all ages. Ben Parfitt, in Over-cutting and Waste in British Columbia's Interior, estimated that one or more non-pine tree is being harvested for every two infected/dead pine trees. Additionally, once clear-cut the stand of trees replanted will be largely of the same age and once old enough to be susceptible to a pine beetle attack the whole stand of trees will be infected and preventative measures cannot be used. Several studies have shown that clear-cutting practices used in the past have contributed to the severity of beetle infestation due to a lack of age diversity among the trees.

Removing all above-ground biomass and subjecting the soil to heavy mechanical disturbance to prepare for tree planting may, in some cases, encourage faster growth of new crop, but is likely to result in relatively higher soil carbon emissions than other harvesting and regeneration methods. Maintaining woody debris and standing trees for partial shade while minimizing soil disturbance may reduce early tree-growth rates, but can have the benefits of lower carbon emissions and retaining larger carbon stocks on site. A study completed by Dr. Fredeen showed that salvage logging will contribute to increased carbon dioxide emissions, as it can disturb the forest-floor plant life and soil. Fredeen found that carbon dioxide monitoring stations above infested areas have, in their first year, shown a six-fold increase in carbon emissions above logged plots compared to infested areas left to decay[2]. Additionally, boreal/sub-boreal regions in Canada are estimated to hold 65-104 Gt of carbon within the soil or eight times the amount stored in the plant biomass.

A study completed by University of Northern British Columbia showed that clear-cuts were clear sources for carbon dioxide 5 to 6 years after harvesting not becoming sinks for carbon dioxide until sometime between 8 to 10 years[3]. They found that clear-cuts are net carbon sources for 8 years because the below ground respiration exceeds photosynthesis which equal losses of a total of 33 tonnes per hectare over 8 years. Soil disturbance and increased rates of decomposition in soils can lead to emission of carbon into the atmosphere, with increased soil erosion and leaching of soil nutrients further reducing the potential for the area to act as a sink for carbon. Scientists estimate that the total potential carbon sequestration in world soils could be as much as 1.2 Gt per year depending on management practices and amount of nitrogen. They concluded that partial cut harvesting conserves the greatest amount of carbon because it have the lowest impacts on soils and leaves the secondary structure intact. However, partial cut harvesting, if not managed well, can result in 'junk' forests with little economic and habitat value.

4.0 CONCLUSIONS

The current pine beetle attack in British Columbia is the largest attack in recorded history, affecting 13.5 million hectares. The carbon dioxide emission estimates for the dead lodgepole pine are 990 million tonnes, which is higher than the estimated annual carbon dioxide emissions for all of Canada. This estimate, however, does not reflect the harvesting methods nor the lost potential carbon sequestration capacity of healthy trees cut down as by catch during a clear-cut. Ultimately, protecting and allowing the understory and secondary structure of stands to grow and dominate the stands will change the composition and structure of the stands. The stands will not be dominated by even aged lodgepole pine, the ideal composition for loggers wanting to make a profit. Markets will need to open up for other species and management practices will need to change. Ultimately if we continue to clear-cut and replant lodgepole pine species we will be setting ourselves up for another catastrophe in 60 to 80 years. While there are 20 to 30 percent of stands that do not have adequate secondary structure to regenerate on their own, the other 60 to 70 percent of stands could provide environmental and socio-economic benefits during the midterm.

In the midterm small-scale treatments such as patch cuts and selection harvesting for infested trees, pheromone baiting, helicopter logging of infested areas, mosaic burning, partial cutting for specific species, age class manipulations and thinning are all strategies to reduce carbon emissions associated with clear-cutting as well as help to prevent further mountain pine beetle attacks. Additionally, increasing soil carbon sequestration though judicious land use and recommended management practices such as adding high amounts of biomass to the soil, reduction in soil disturbance, improved soil structure, enhancing microbiotic activity and increasing species diversity of soil fauna and strengthening mechanisms of elemental cycling will also reduce emissions and increase productivity. Using these management practices, soil sequestration can be sustained for 20 to 50 years or until the soil sink capacity is filled.

REFERENCES

1] Walton, A., Hughes, J., Eng, M., Fall, A., Shore, T. and Riel, B., (2008)."Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the infestation projection based on the 2007 Provincial Aerial Overview of Forest Health and revisions to the 'Model' (BCMPB.v5)", Report, Ministry of Forests and Range, Retrieved on 4/2009 from http://www.for.gov.bc.ca/hre/bcmpb/BCMPB.v5.BeetleProjection.Update.pdf

[2] Fredeen, A. L., 2006. "How is Forest Management Influencing Carbon Storage in Sub-Boreal Forests?", Natural Resources and Environmental Studies Institute, Research Extension Note #06.01, University of Northern British Columbia, Retrived on 4/2009 from http://web.unbc.ca/~fredeena/Fredeen%20REN%202006.pdf

[3] Fredeen A. L., Waughtal J. D., and Pypker, T. G., (2007). "When Do Replanted Sub-Boreal Clearcuts Become Net Sinks for CO2?", Forest Ecology and Management, Vol. 239, pp. 210-216, Retrieved on 4/2009 from http://web.unbc.ca/~fredeena/Fredeen%20et%20al.%202007%20FEM.pdf.

[4] Parfitt, B., (2007). "Over-Cutting and Waste in B.C.'s Interior: A Call to Rethink B.C.'s Pine Beetle Logging Strategy", Report, Canadian Centre for Policy Alternatives, Retrieved on 4/2009 from http://www.bcfed.ca/files/bc_overcutting_woodwaste.pdf.

[5] Richards, K. R., Sampson, N. R. and Brown, S., (2006). "Agriculture and Forestlands: U.S. Carbon Policy Strategies", Report, Pew Center on the Global Climate Change, Retrived on 4/2009 from http://www.pewclimate.org/docUploads/Agricultural%20and%20Forestlands-U.S.%20Carbon%20Policy%20Strategies.pdf.

[6] Coates, K. D., DeLong, C., Burton, P. J. And Sachs, D., L., (2006). "Abundance of Secondary Structure in Lodgepole Pine Stands Affected by the Mountain Pine Beetle", Report, Retrieved on 4/2009 from http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/report.pdf.

[7] O'Laughlin, J. and Mahoney, R, (2008). "Forests and Carbon", Woodland Notes, Vol. 19, No. 2, Retrieved on 4/2009 from http://www.cnr.uidaho.edu/extforest/Woodland%20NOTES.htm.

[8] Pachauri, R.K. and Reisinger, A., (Eds.), (2007). "Climate Change 2007 Synthesis Report", International Panel on Climate Change, Geneva, Retrieved on 4/2009 from http://www.ipcc.ch/ipccreports/ar4-syr.htm.

[9] ___, (2007). "Lodgepole Pine Stand Structure 25 Years After Mountain Pine Beetle Attack", Report, Forest Practices Boards, Retrieved on 4/2009 from http://www.fpb.gov.bc.ca/assets/0/114/178/184/360/39218c7d-9e93-4fef-9597-3375076bcd75.pdf.

07.
"WATER, WATER... NOT EVERYWHERE"
Water Conservation in Healthcare Buildings

Breeze Glazer, LEED® AP, *breeze.glazer@perkinswill.com*

ABSTRACT
The conservation of water across the globe is not a concern for the future, but a pressing issue for us to face today. This issue is of even more importance with regard to the healthcare sector, where the values of health and sustainability are intrinsically linked.

This paper explores the application of water throughout the healthcare setting - from source to sewer - and examine the multitude of uses where conservation interventions are both possible and necessary. Ranging from uses that require limited intervention to achieve reduced potable water demand such as the elimination of potable water for landscaping irrigation to those that require extensive technologies such as the on-site treatment of greywater and black water - potable water reduction is achievable through a broad range of strategies that any facility could adopt.

Several recent healthcare case studies will demonstrate the applicability of these strategies. Finally, the paper introduces the relationship between water and embodied energy and reveals the necessity of a two fold strategy to promote these linked efficiencies.

KEYWORDS: healthcare, LEED, sustainability, water conservation, potable water, xeriscape, irrigation.

1.0 INTRODUCTION
The conservation of potable water across the globe is no longer just a concern for the future, but a pressing issue today. According to the 2nd United Nations World Water Development Report, two-thirds of the world's population will live in areas of water stress by 2025 - it is not a localized issue for disparate areas, but instead a globally shared responsibility that calls for a united stewardship (Figure 1)[1]. Within the United States, almost half of the country faces freshwater shortages as of July 2008 – based on the Palmer Drought Index 27 percent of the country faces moderate to extreme drought, while 15 percent of the country faces severe to extreme drought. This issue is being addressed by communities and policy makers alike - from raising water, sewer and stormwater rates to providing municipal

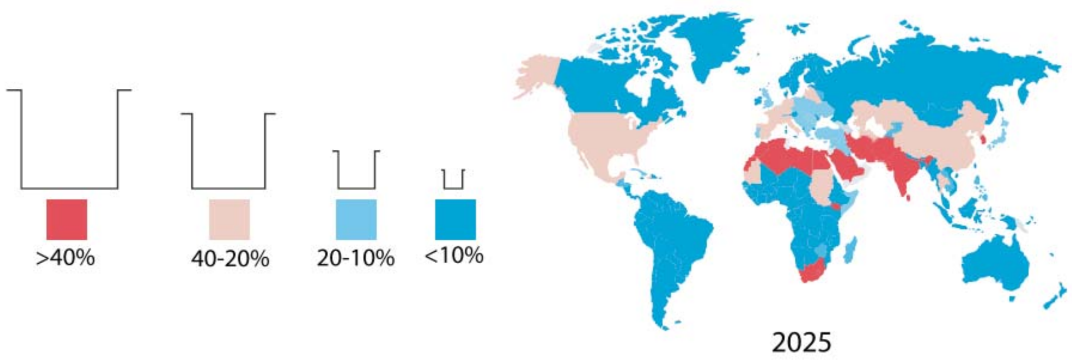


Figure 1: The map projects how much water will be withdrawn with respect to the amount that is naturally available by 2025. Courtesy of World Business Council for Sustainable Development, 2005

reclaimed water for irrigation and process uses. On a local level, the commitment to water conservation has carried down to individual homeowners, corporations and public institutions. Often the largest employer in their community, hospitals occupy a unique leadership position and have an opportunity to demonstrate responsible potable water use and serve as stewards of the environment. The issue of water quality and contamination is beyond the scope of this paper, however it is easy to make the link between global health and the availability of potable water.

1.1 Water Use in Healthcare

Water conservation measures should be at the forefront of the healthcare sector's sustainability agenda. In many communities, hospitals are among the top ten water users. The United States DOE Federal Energy Management Program ascribes water use indices that can be used a baseline measurement for various sectors - healthcare dominates overall water use averaging between 80 and 150 gallons per bed per day for total water consumption. In many regions of the US, nonprofit hospitals are exempt from water and sewer fees, a situation that dampens interest in metering, tracking, or reducing potable water consumption. Even in areas

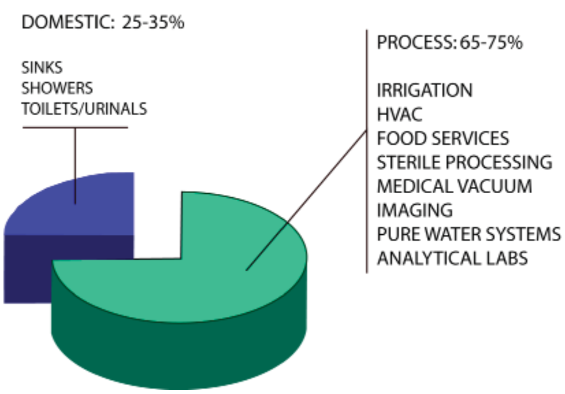


Figure 2: Water use in a typical healthcare facility. Courtesy of Practice GreenHealth.

of the country with abundant water supply, the sector must balance the duality between complex programs that consume massive amounts of water in relation to their mission and intrinsic values of health and sustainability. The current state of water conservation in healthcare applications will be explored, looking both at the industry as a whole as well as healthcare case studies. These selected projects reflect the pioneers that have recognized water conservation as an issue central to their overarching mission, informing their understanding of healthcare and sustainability. By looking at the different categories of water use within that average, we can identify achievable conservation strategies for each tier of feasibility to dramatically reduce overall water consumption (Figure 2).

2.0 IRRIGATION FOR LANDSCAPING

There are a number of water uses within a healthcare facility that do not require potable water and instead can use recycled, reclaimed and harvested water to reduce overall consumption. The elimination of potable water use for landscape irrigation is a practical form of water conservation that most projects can attain through the strategies outlined below. This relative feasibility is recognized by analyzing a sample of 30 of the LEED certified healthcare buildings in the United States. While the certification levels for these projects range greatly from Certified to Platinum - 69 percent achieved the total elimination of potable water for landscaping irrigation. These projects are located throughout the United States in areas of both drought and water abundance, a consistency that reflects the importance of water conservation and the recognition that it is as much as a universal problem as it is a shared resource with a finite supply.

2.1 Xeriscaping

Primarily, the elimination of potable water for irrigation can be achieved foremost with the landscaping choices themselves - projects can choose to xeriscape rather than using non-native landscaping elements that require permanent irrigation on an annual basis. Xeriscaping utilizes only native or adaptive vegetation that can typically survive solely on annual rainfall instead of supplemental potable water. Utilizing native vegetation often yields additional benefits ranging from reducing landscape maintenance issues and eliminating the use of harmful pesticides or fertilizers while also helping to reduce storm water run-off. A downside of xeriscaping is the potential inconsistency of the appearance of the landscaping throughout the year - what is green, lush and "healthy" in appearance during one season might be brown and dry during another. While this is reflective of the natural cycle of vegetation, it can affect the aesthetic and emotional appearance of a hospital to a patient or visitor. Many therapeutic or "healing" gardens continue to employ landscaping elements that require irrigation. However, providing required irrigation water-does not necessarily mean a dependence on potable water, but instead calls for a more involved strategy of using either non-potable collected rainwater or previously used process water such as HVAC condensate delivered through non-aerosolized drip irrigation systems. In some instances, municipalities are providing piped reclaimed water systems for irrigation as well as other process uses.

2.2 Condensate Capture

Condensate is naturally produced when air passes over the cooling coils of a HVAC system. Normally, it is simply drained into the waste water system and sent for municipal treatment along with other effluents. However, it is potentially a high quality, uncontaminated water source that can alternatively be captured and used for landscape irrigation without substantial alterations to a baseline HVAC piping system. Other types of equipment such as refrigerators or icemakers that have cooling coils also produce condensate that can be captured and reused. The Emory Winship Cancer Institute in Atlanta, Georgia recovers approximately 800,000 gallons

Figure 3: The Discovery Health Center

of condensate per year from their HVAC system cooling coils[2]. Healthcare projects, particularly in warm, humid environments such as the southeast United States, should consider utilizing condensate capture for their irrigation needs.

2.3 Rainwater Harvest

Captured rainwater can provide a substantial water source for landscaping needs and has been utilized by a number of healthcare facilities across the country including Geisinger Health's Gray's Woods Hospital in Port Matilda, Pennsylvania, Dell Children's Medical Center of Central Texas, Austin, and the recently CaGBC LEED® certified Upper River Valley Hospital in New Brunswick, Canada. This strategy offers an additional environmental benefit of reducing, or even completely eliminating site storm water runoff. Captured rainwater

Figure 4: The natural hydrology of the site is celebrated in the building.

can be stored in underground tanks or cisterns, this practice allows the rainwater to be harvested during those times of abundance and then used throughout the year as needed. Regulations often require healthcare facilities to have underground water storage tanks for domestic water supply during times of catastrophe or for fire suppression systems. Some projects utilize the same tanks to store captured rainwater. The Discovery Health Center, Harris, New York (Figures 3 & 4) and Oregon Health & Science University Center for Health and Healing, Portland, Oregon use captured rainwater to recharge their blackwater sewage conveyance system. Rather than mixing water sources while utilizing a single tank, a dual tank system might be a more practical option because each water source has to be treated only to the degree required for its anticipated use.

2.4 Bioswales and Retention Ponds

While an underground tank can be considered a strictly systematic approach to harvesting rainwater or building or irrigation uses many facilities have instead chosen to celebrate their rainwater capture and stomrwater management strategies through highly visible means including bioswales, green roofs and retention ponds. Bioswales are naturally vegetated drainage courses that help prevent silt and ground pollution from entering the

Figure 5: Boulder Community Foothills Hospital, designed by OZ Architecture
Image Courtesy of OZ Architecture

storm water system while storing and absorbing rainwater from impervious surfaces. Many facilities have located bioswales throughout surface level parking areas to capture rainwater runoff while also contributing to a reduction in the heat island effect. A number of healthcare facilities utilize bioswales to address stormwater including Boulder Community Foothills Hospital in Boulder, Colorado, designed by OZ Architecture, and Metro Health in Wyoming, Michigan (Figure 5). Alternatively, if available land area permits, a retention pond is another strategy for harvesting rainwater for landscape uses while also providing aesthetic value and has been utilized by healthcare facilities across the globe. A retention pond might be a better option than bioswales in geographic areas that receive a great deal of rainfall during a relative short amount of time, however they require appropriate grading to ensure proper drainage across the site.

3.0 PROCESS WATER - MEDICAL USE

There are a number of large volume process water demands in a typical healthcare facility that can be substantially reduced through best practices and can utilize non-potable sources such as captured rainwater. Process water is any water application that does not fall under the Energy Policy Act of 1992 - meaning, essentially, does not flow through a conventional water closet or lavatory/bathing fixture unit. Within a typical hospital as much as 70 percent of potable water is used for process water applications including HVAC, food services and medical equipment[3]. These applications often use treated, potable water for a single use in an open loop cycle, yet could operate within a closed loop system without any negative impact. When these systems and technologies were first brought onto the market, water was viewed as an abundant resource that was in infinite supply. Developing closed loop systems was simply not considered a necessary strategy. Similar to water-cooled air compressors in typical HVAC systems, these traditional medical systems operate by using water to cool air during the compression phases and then discharges it into the waste water system after a single use. However, it is possible to close the loop and re-circulate water with the introduction of a properly designed chiller system that can provide the required cooling properties instead[4]. Simply specifying an air cooled HVAC system instead of a water cooled one will immediately offer substantial water reductions. With water demand rising and supply decreasing, one can anticipate a rise in the current, relatively low cost of water charges in most municipalities. If a healthcare facility is making the investment now in new equipment, the financial savings in the future from the reduction of both potable water consumption and discharge can be used to help offset any increased costs of switching to an air-cooled HVAC system.

3.1 Sterilization Equipment

Sterilization equipment is a major consumer of potable water in healthcare facilities, using on average between 60-300 gallons of water per hour - up to 7,200 gallons per day[4]. In busy healthcare facilities, steam sterilizers are often left on throughout day and night, continuously discharging potable water into the sewer. The introduction of an automatic shut-off valve will prevent water flowing into the unit when it is not in use. Another stream of water use in sterilizers is to temper the hot condensate produced before it is sent to the waste water system, where high temperatures can damage pipes, drains or ecological systems in water bodies[4]. It is possible to greatly reduce this water demand through the introduction of steam condensate tempering systems on new or existing sterilizers which use high temperature sensing probes to monitor the drain temperature and applies chilled water only when needed[4]. It is also possible to reuse the steam condensate and non-contact cooling water from sterilizers for the make-up water required by HVAC cooling towers or boilers[4].

3.2 Imaging

Imaging is traditionally another major consumer of water in healthcare facilities, yet solutions are available to dramatically lower consumption. While many healthcare facilities have switched to digital imaging, some still utilize the traditional x-ray process that uses large amounts of potable water in a once through processing cycle[4]. A stream of water is used to rinse the film of excess chemicals and to halt the development process. For these applications, it is possible to introduce or retrofit a re-circulating device that reuses rinse bath water for make-up water in the developer solution and can reduce water consumption by over 90 percent[4].

3.3. Medical Vacuum

Medical vacuum systems are another area that utilize large amounts of potable water, but can benefit from water conservation measures. Water is used in a medical vacuum to act as a seal, lubricant and a cooling system, consuming up to 1,200 gallons of water per hour[5]. However, dry vacuum pumps are available that either use no water at all or a greatly reduced amount. Dry vacuum pumps also offer a higher level of energy efficiency compared to water driven systems as it requires less energy to move air instead of water through the system. If it is not viable to switch to a dry vacuum system, it is possible to introduce a closed loop system that re-circulates and chills the process water through the cooling tower and back to the vacuum system for reuse[5]. There are other types of medical equipment that can typically use once through cooling water such as CAT scanners or air compressors, but can also be specified to operate within a closed loop system. It is vital for architects and engineers working in the healthcare field to be vigilant and inquisitive - rather than specifying the same piece of equipment that has been field tested and trusted for years, it can often pay to ask questions and investigate whether acceptable, water efficient alternatives are available.

4.0 PROCESS WATER USES - NON MEDICAL USES

There are also non-medical areas of equipment use where water conservation measures can be implemented. Relatively minor pieces of equipment can be major consumers of potable water and are not always considered when implementing conservation measures. For example, ice machines are used throughout hospitals for a number of different purposes with water-cooled models requiring more water to cool the system then to even make the ice itself. Water-cooled ice makers require between 130-180 gallons of cooling water to produce 100 pounds of ice - up to 720 gallons per day or 262,000 gallons a year[6]. These are staggering figures, particularly when considering potable water is used in a once through cycle. However, air-cooled units exist that do not use any water for cooling purposes and can drastically lower water consumption and, in fact, some municipalities provide rebates to help offset any cost difference when retro-fitting[7]. However, it should be noted that although air-cooled models eliminate the need for cooling water, they can be up to 20 percent more energy intensive and one should select an EnergyStar rated model[8]. As with medical equipment, architects should be vigilant when specifying other pieces of equipment that can potentially utilize potable water in an irresponsible matter - there are often alternatives available.

5.0 REGULATED WATER

After successfully reducing process water consumption in healthcare facilities, regulated water should be targeted as well. The EPA act of 1992 regulates domestic fixtures that consume water including sinks, showers, water closets and urinals - these uses are on average approximately 25-35 percent of total consumption in healthcare facilities[9]. There can be a cultural stigma against water conserving toilet fixtures - facility managers may believe that they are less sanitary, require more maintenance or do not operate as well. However, there is little evidence to support the concern with the new generations of low consumption or dual flush fixtures. Architects should work to overcome these perceptions with healthcare operators and owners and convey that because automatic shut off sinks or sensor operated toilets, urinals and sinks reduce hand contact, the threat of contamination is also potentially reduced. The Maximum Performance of Toilet Fixtures (MaP) matrix evaluates the performance of efficient fixtures by manufacturer in their solid waste removal ability - it was generated by Veritec Consulting and can easily be found on the internet. It is this type of informed, independent research that should be used by designers to help guide hospital facility managers through fixture performance evaluation. Flow reducers should be installed on all applicable plumbing fixtures in a facility, in addition to automatic shutoff valves, motion sensor faucets and low flow showerheads. These measures, in addition to low flow and dual flush toilets and urinals can greatly reduce overall domestic water consumption, over 60 percent of the current LEED® certified healthcare projects achieved a 30 percent reduction over the baseline for regulated water consumption reflecting the relative feasibility of this approach.

6.0 GREYWATER REUSE / HEALTHCARE CASE STUDIES

Several healthcare facilities from across the globe have taken even greater strides to reduce domestic water consumption through a number of innovative strategies that can work as a roadmap for future facilities. Waitakere Hospital in New Zealand, a 120-bed inpatient and ambulatory care facility designed by Di Carlo Potts & Associates, is a healthcare pioneer for water conservation and has served as a shining example for future facilities. With storm water management a major issue in the area, the hospital strove to effectively deal with all rainfall on the site. A system of high capacity gutters, vegetated bioswales, a retention pond and water storage tanks work in tandem to responsibly deal with the annual site rainfall[10]. The storm water management system utilizes the bioswales and retention pond to naturally filter storm water runoff of silt and pollutants, capturing some for irrigation purposes while releasing excess into an adjacent creek[10]. Rainwater is harvested from the building's roof and is used for domestic sewage conveyance, a first in the world for a healthcare facility. Waitakere Hospital chose to celebrate their water conservation measures by revealing them in the design of the facility - the rain gutters are articulated and featured prominently on the facade of the building while both the bioswales, retention ponds and storage tanks are visible from the hospital.

6.1 Blackwater Reuse / Healthcare Case Studies

If Waitakere Hospital was the pioneer, Oregon Health & Science University Center for Health and Healing can be seen as the successor, currently holding the record for the most ambitious water conservation strategies in a healthcare building to date. The 400,000 SF LEED Platinum facility was designed by GBD Architects in conjunction with Interface Engineering and opened in 2006[11]. The Center for Health and Healing functions as a medical office building while offering space for biomedical research, outpatient surgery and clinical studies. Although often thought of as a wet city, Portland, Oregon receives significantly less annual rainfall - 36 inches, than places such as New York City - 50 inches. Those factors, in combination with the City of Portland having particularly high local fees for water use and discharge resulted in the project architects focus on water conservation for the project while setting a goal of achieving an efficiency 50 percent greater than code[11]. Potable water from the municipal supply is used at OHSU Center for Health & Healing for only approximately 44% of total site consumption including drinking fountains, food preparation, showers and hand washing - in addition to sewage conveyance in the clinical areas[11]. Harvested rainwater, reclaimed groundwater and treated grey- and blackwater are the additional sources for building water consumption, a complex system of strategies that work in tandem to achieve a high level of efficiency.

Harvested rainwater from the green roof and reclaimed groundwater is stored in the building's fire suppression system underground tanks, which were already required by code. The design team oversized them to compensate for any additional required volume[11]. This water source is used to directly provide water for the cooling tower makeup, a radiant cooling system and landscape irrigation. All water discharged from the building's domestic systems including toilets, showers and sinks is sent to an on-site, underground aerobic digester that treats it to a Class 4 Standard[11]. The digester

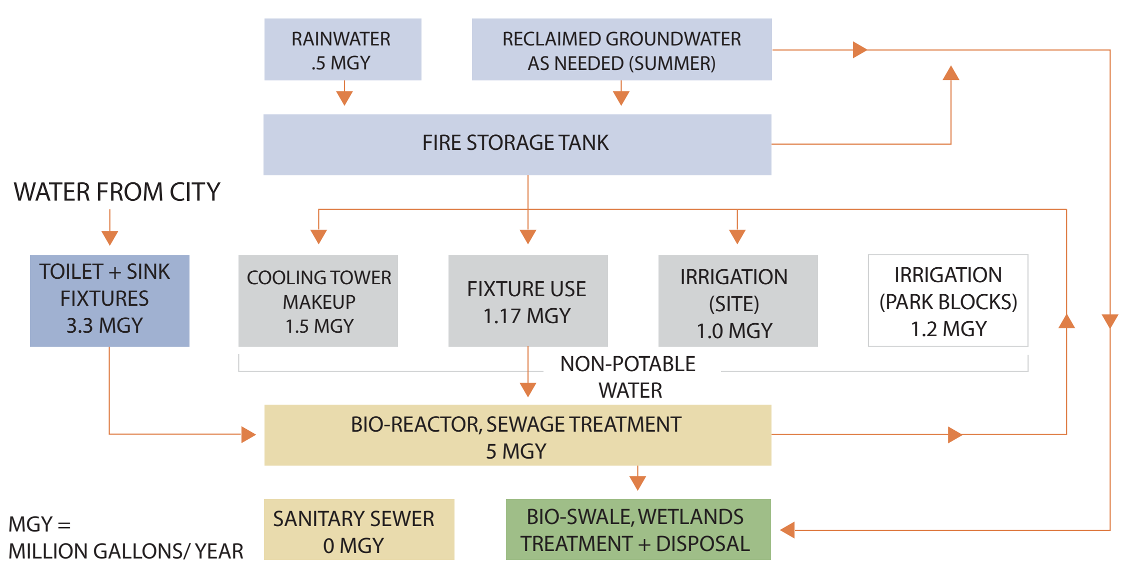


Figure 6: Building water conservation flows. *Diagram Courtesy of Interface Engineering*

was designed, built and is owned and maintained by a 3rd party who is contracted by the building and charge a negotiated monthly fee. The treated water is then recirculated throughout the building and used for sewage conveyance, irrigation and cooling tower makeup[11]. While a unique set of parameters allowed the developer owned and operated OHSU Center for Health & Healing to pursue these extensive water conserving measures from a fiscal standpoint, the project should serve as an effective model that demonstrates a number of different strategies that future projects can explore.

In water challenged regions of the country, municipalities are beginning to install reclaimed and recycled water systems with the intent of replacing potable water

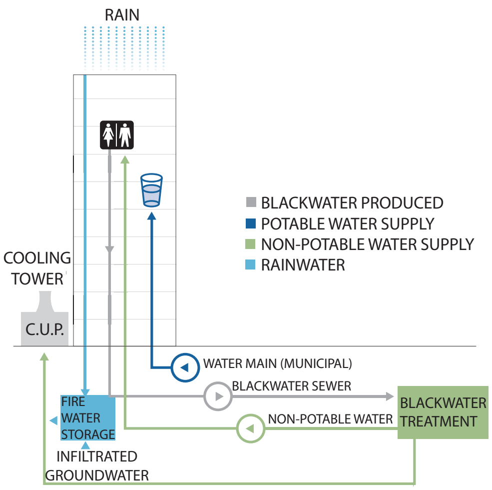


Figure 7: Total water system management at OHSU.
Diagram Courtesy of Interface Engineering

for sewage conveyance with reclaimed sources. This system approach requires segregating water supply piping to water closets from that of lavatories and sinks – a system modification that is relatively easy to achieve in new construction but a complex and costly retrofit. Project teams are encouraged to strategically question and challenge health care owners investing in major new projects to be pro-active in considering the long term flexibility to meet potable water challenges in their communities.

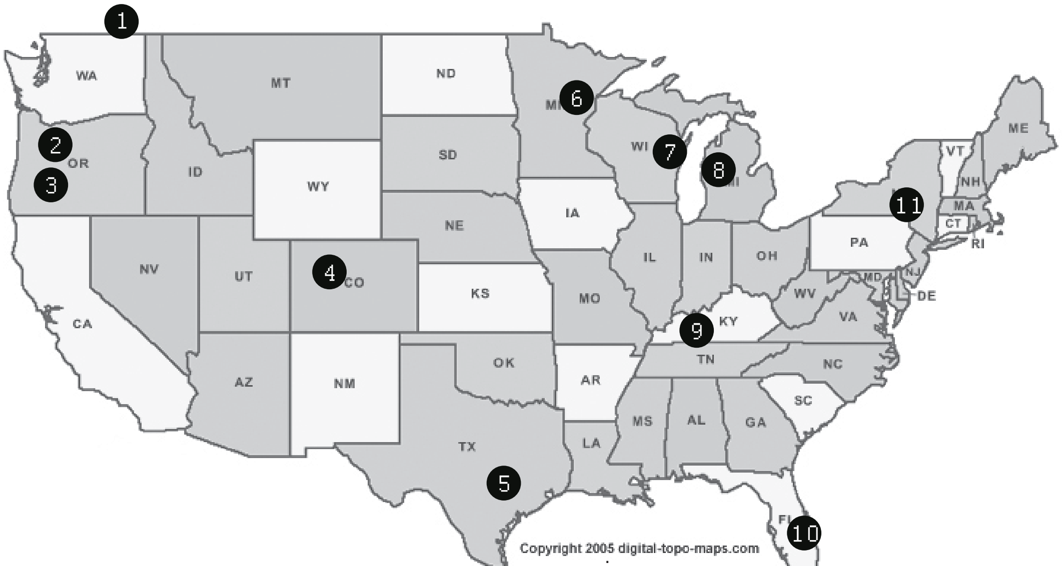
7.0 WATER AND ENERGY

Finally, a new component of water conservation and efficiency has emerged only recently - termed "watergy" it describes the fundamental relationship between water and energy. While conservation and efficiency measures reduce water consumption, they also have a direct effect on the embodied energy of that water. When water appears instantly from a faucet or showerhead, one doesn't question how that water arrives or leaves, let alone how it was treated to potable standards in the first place. However, a large amount of energy is required by water treatment plants and the distribution systems that link them to our homes, businesses and institutions. California has estimated that water treatment and distribution consumes approximately 19 percentage of all electricity and 30 percentage of all natural gas in the state while Atlanta recently announced that 28 percentage of all carbon emissions from city controlled entities are related to wastewater treatment - a staggering figure[12,13]. While these reports are still somewhat isolated and not widely distributed, the embodied energy of potable water will hopefully soon become a major focus of sustainable efforts and recognized by certification systems such as LEED. Regardless of public awareness, architects must accept this link and realize the positive impact on carbon reduction that emerges from water conservation.

8.0 CONCLUSION

By now it is clear that the quantity of clean water on earth is rapidly eroding due to a lack of responsible planning or management - the time has come to start recharging our aquifers and reservoirs by drastically lowering consumption of potable water. The goal of this document is to give a broad overview on the various areas within a typical healthcare building that consume potable water and can benefit from water conservation and efficiency measures. Through the innovation and intervention of the design and engineering professional, these measures can drastically reduce the consumption of potable water. The healthcare projects presented have successfully introduced strategies to do just that, functioning as case studies that should inform our own work. These pioneering projects have taken on a united responsibility and environmental stewardship with the notion that natural resources are a shared and universal commodity. It is the architect's ethical duty to move past the tried, tired and unsustainable systems of the past and help lead others towards a sustainable future.

Figure 8 on the following page shows a summary of LEED certified healthcare projects that have achieved a measurable reduction in the consumption of potable water and should be utilized as case studies to inform future design work. Design teams might want to explore the case studies in their respective geographic area to identify effective strategies that have been realized.



1 **Upper River Valley Hospital** / **ADI Architects - New Brunswick, Canada 2009**
Stormwater management includes bioswales, retention ponds, and oil-grit separation chambers. Rainwater harvest for sewage conveyance and process water use all contribute to a high level of water efficiency.

2 **OHSU Center for Health & Healing** / **GBD Architects - Portland, Oregon 2006**
Complete water conservation strategies includes rainwater harvest and groundwater reclamation for process uses. Greywater and blackwater is treated onsite for process uses and sewage conveyance needs for a 62% potable water use reduction.

3 **Providence Newberg Medical Center** / **Mahlum Architects - Newberg, Oregon 2006**
Stormwater management includes bioswales in parking areas. The site is xeriscaped using native vegetation with a 50% reduction in potable water use for irrigation. A closed loop cooling water system and efficient domestic fixtures with automatic sensors contribute to a 20% potable water use reduction.

4 **Boulder Community Foothills Hospital** / **OZ Architecture - Boulder, CO 2003**
Stormwater management includes bioswales and the extension of an existing wetland on the site. The site is xeriscaped using native vegetation with a 50% reduction in potable water use. Efficient domestic fixtures in addition to waterless urinals in non-critical areas contribute to a high level of water efficiency.

5 **Dell Children's Medical Center** / **Karlsberger - Austin, TX 2007**
The site is xeriscaped with native vegetation with a rainwater harvest system used for irrigation when needed. Efficient domestic fixtures including dual flush toilets contribute to a high level of water efficiency.

6 **St. Mary's Duluth Clinic / HKS Architects -Duluth, Minnesota 2006**
The site is xeriscaped using native vegetation and uses no potable water for irrigation. A closed loop cooling water system and efficient domestic fixtures contribute to a 30% potable water use reduction

7 **Affinity Medical Group Clinic** / **Boldt Construction - Brillion, Wisconsin 2007**
Stormwater management plan includes a retention pond and proper site grading. The site is xeriscaped using native vegetation and uses no potable water for irrigation. Efficient domestic fixtures contribute to a 30% potable water use reduction.

8 **Metro Health Hospital** / **HDR Architecture - Grand Rapids, Michigan 2007**
Stormwater management plan includes an extensive green roof, bioswales and rain gardens throught the site. The site is xeriscaped using native vegetation, reducing the use of potable water for irrigation. Efficient domestic fixtures including waterless urinals and low-flow faucets contribute to a 20% potable water use reduction

9 **Jewish Hospital Medical Center** - Louisville Kentucky 2006
The site is xeriscaped using native vegetation and uses no potable water for irrigation. Efficient domestic fixtures including dual-flush toilets contribute to a 30% potable water use reduction.

10 **Parrish Healthcare Center at Port St. John** / **RTKL - Cocoa, Florida 2007.**
Stormwater management plan includes retention ponds and the extension and protection of an existing wetlands. Site is xeriscaped using native vegetation and uses harvested rainwater for irrigation. Efficient domestic fixtures includ-ing low flow toilets, waterless urinals and dual flush toilets reduce potable water use by 30%.

10 **Discovery Health Center / Perkins+Will (Guenther5) - Harris, NY 2004**
The site utilizes native and adapted vegetation and uses no potable water for irrigation. An existing stream was returned to its' natural flow on the site. Rainwater is harvested for the sprinkler system and irrigation. Efficient domestic fixture include low flow toilets and occupant controls to help reduce potable water.

Figure 8: Healthcare project case studies with comprehensive water strategies.

REFERENCES

[1] Fry, A. and Martin, R., (Eds.), (2005). “Water Facts and Trends”, World Business Council for Sustainable Development, Geneva.

[2] Johnson, G., (2008). “HVAC Design for Sustainable Lab”, ASHRAE Journal, September, pp.25-26.

[3] ___, (2006). “Water Conservation Strategies”, Practice Greenhealth Green Guide for Healthcare Series, April 7, Retrieved on 4/2009 from www.practicegreenhealth.org/tools/webinars/archive/archive/244.

[4] ___, (2006). “Facilities Management—Water Conservation”, Healthcare Environmental Research Center, Retrieved on 4/2009 from www.hercenter.org/facilitiesandgrounds/waterconserve.cfm.

[5] ___, (2008). “A Water Use Efficiency Plan Review Guide”, Eastbay Municipal Water District.

[6] Federal Energy Management Program. Retrieved on 4/2009 from www1.eere.energy.gov/femp/procurement/eep_ice_makers.html.

[7] Air Cooled Ice Machine Rebate. www.santafenm.gov/index.asp?NID=1172(accessed April 2009).

[8] Federal Energy Management Program. Retrieved on 4/2009 from www1.eere.energy.gov/femp/procurement/eep_ice_makers.html.

[9] ___, (2006). “Water Conservation Strategies”, Practice Greenhealth Green Guide for Healthcare Series, April 7, www.practicegreenhealth.org/tools/webinars/archive/archive/244 (accessed April 2009).

[10] Oberlin, J., (2008). “New Zealand Hospital Focuses on Stormwater Conservation”, Healthcare Design Magazine, December, Retrieved on 4/2009 from www.healthcaredesignmagazine.com/ME2/dirmod.asp?sid=&nm=&type=Publishing&mod=Publications%3A%3AArticle&mid=8F3A7027421841978F18BE895F87F791&tier=4&id=E4F67AC721A94C6D8047E7AFC605C7E

[11] ___, (2005). “Engineering a Sustainable World”, Interface Engineering, Retrieved on 4/2009 from www.ieice.com/portfolio/green_building/book/book.html.

[12] ___, (2005). “California’s Water-Energy Relationship: Final Staff Report”, Report, California Energy Commission, Retrieved on 4/2009 from http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF.

[13] ___, (2008). “Our Path To Sustainability”, Sustainability Report for Atlanta, Retrieved on 4/2009 from http://www.sustainableatlanta.org/Data/Sites/1/sareport.pdf.

AUTHORS

01./ 05. 

AJLA AKSAMIJA

Ajla received her PhD in architecture with an emphasis on technology and environment. She monitors latest developments in building systems theory, materials, technology and building performance to identify areas of interests and applicability to Perkins+Will design projects. She has contributed to several books, written numerous research articles and has presented at national and international conferences.

02. 

KALPANA KUTTAIAH

Kalpana is a licensed architect with a master's degree in architecture. She has 23 years of professional experience with expertise in research and innovation. In her role as the firmwide healthcare research manager and a long career and background in architecture, research and practice, informed by varied cultural experiences and relevant applicability, her passion for sustainability and innovation, tenacity for learning and motivating others to learn, she brings great leadership to our healthcare research and innovation.

02. 

JIM BYNUM

Jim has over 23 years of professional experience as an architect and planner. As a director for the Perkins+Will Healthcare Planning and Strategies group, Jim has experience in both healthcare and higher education planning. He has directed planning efforts for some of Perkins+Will's largest and most complex clients. He represents the principal/doer model of Perkins+Will. As a principal and senior planner, he leads and participates in the planning process as well as ensuring that the solutions support the client's strategic goals.

02. 

ROBIN GUENTHER

As a principal at Perkins+Will and a national leader in the conversation linking public health, regenerative design and sustainability. Robin is particularly skilled at achieving consensus for sustainable ideas, a quality valued by clients as well as the many advocacy groups with whom she works. Her work has helped shape healthier, more welcoming facilities for nearly every medical institution in New York City.

03. 

MICHAEL DRIEDGER

Michael is a LEED® Canada Accredited Professional with 15 years of experience working in the construction trades and in architecture. His diverse work experience has helped develop his talents in contract administration, project management and LEED coordination on a range of projects within the commercial, healthcare, residential, municipal and recreational sectors. He graduated from the University of Saskatchewan with a bachelor of arts and followed this with studies in architecture and building engineering technology from the British Columbia Institute of Technology(BCIT).

AUTHORS

MICHELLE HALLE STERN

04.

Michelle is a registered architect and engineer with 20 years of diversified experience in the architectural industry. She specializes in sustainable design and joined the Perkins+Will team to focus on this key issue in building designs, especially healthcare facilities. Michelle is a respected speaker and educator on environmental issues. She is a strategic thinker with a successful record of building consensus and a passion for developing strong client and team relationships.

TOM MOZINA

04.

Tom is an associate principal and senior designer who has served in lead design roles on a variety of building types. His most notable projects include: Los Angeles United States Courthouse, a 30-story corporate office tower for Bank of America, Peggy Notebaert Nature Museum and a 30-story mixed-use single family residence in Mumbai, India. He served as co-director of the firm's sustainable design initiative where he developed and helped implement the SDI strategic plan.

GAIL BORTHWICK

04.

Gail is a senior architect with extensive experience in green and high-performance design. She contributed to the research for the article on the *'Benefits of Access to Nature in Buildings'* during her tenure at Perkins+Will.

CHESSA A. ADSIT-MORRIS

06.

Chessa joined Busby Perkins+Will after working as a senior consultant for Green Building Services (GBS) in Portland, Oregon. She has worked on a diversity of projects ranging from child care facilities, commercial office, retail and public administration buildings. Chessa acts as a third party reviewer for the CaGBC, completes Life Cycle Analysis assessments, examines issues of carbon reduction strategies through sustainable material selection and is currently completing her master's in applied ecology and resource management.

BREEZE GLAZER

07.

Breeze is a designer who has focused on sustainability in architecture. He has applied this expertise on a variety of projects across a multitude of scales, from branding projects for the Conservation Fund to the New Orleans Mission Family Center, currently tracked to be the first LEED NC Silver building in New Orleans. As a national market sector researcher for healthcare sustainability, Breeze is currently focused on helping to shift healthcare design towards a regenerative model.

PERKINS
+WILL

For more information, please send an email to **pwresearch@perkinswill.com**