# High Performance Buildings

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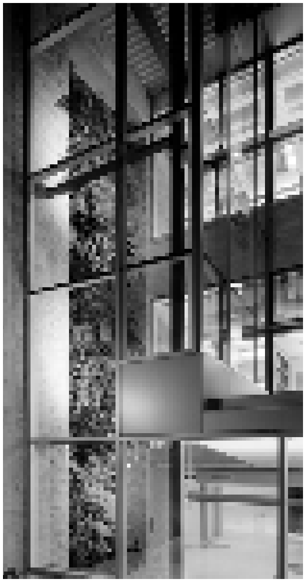
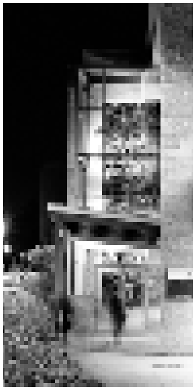
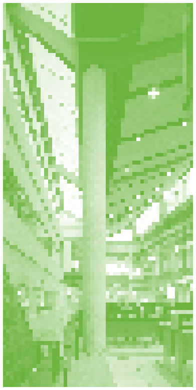
**Opposite page and cover page: Queen's University Beamish-Munro Hall Integrated Learning Centre,** 2007 RAIC medal recipient, SB08 Tokyo Canadian representative and BREEAM/Green Leaf certified national leader (photo credit: Richard Johnson).

# Contents









# INTRODUCTION

**Buildings represent nearly 40% of final energy used globally. If we include the energy consumed in building construction, this number grows to more than 50%.** However, large and attractive opportunities exist to reduce buildings' energy use at a lower societal cost and a higher return than in other sectors.

World Business Council for Sustainable Design,
Energy Efficiency in Buildings

To mitigate the environmental impact that buildings can create, we must raise design and building sustainability standards. As the world's population necessarily becomes more concerned with energy use, we need to think about the global footprint our buildings make, and the multifold advantages to be found in creating more high performance buildings.

The essential nature of true high performance design is that it not only serves to advance sustainable mandates but also serves to increase the positive effect these buildings have on the occupants, urban environment and broader society. These buildings not only save energy, save water and employ healthy materials, they produce greater comfort, produce healthier indoor air quality, provide greater access to natural light and improve the sense of well-being and connectivity of people in general by providing more beautiful living and working spaces.

Tenants and buyers are increasingly choosing properties that are environmentally responsible, ones that will reduce their energy consumption and operating costs. This is true across all sectors, public, private and non-profit, with governments often being the first to implement green building practices in order to set an example. Governments are also setting out new regulations for energy reduction and owners of buildings must meet these targets.

There are already buildings around the world that are exceeding current legislation targets, where people have been able to create living, breathing buildings that can generate their own power, utilize natural winds and topography to regulate their systems, and treat their own waste. Not only are these green buildings efficient, they provide a better environment for people to live and work in with their many attractive and health-benefitting features.

The new generation of buildings are intelligently planned, thriving buildings that provide high returns for low cost and focus on enhancing the relationship between, and the performance of, people and their environment.

**Okanagan College Centre for Learning, Kelowna, Canada**
(photo credit: Desmond Murray)

# PART 1

## THE BUSINESS CASE FOR HIGH PERFORMANCE DESIGN

# Why Sustainable Design?

China's economic development and rapid urbanisation have increased the number of people moving within the country, largely from rural areas to towns and cities...100 million rural migrants arrived in Chinese cities during the last decade and why 300 million country dwellers will migrate to Chinese cities over the next ten years, with three million currently settling in Shanghai every year.

Royal Geographical Society, rgs.org

**Shanghai skyline**
(photo credit: Alex Nikada Photography)

## DWINDLING RESOURCES

# **Between now and 2020**, global energy demand is projected to rise by an average 2.2% per year, the majority occurring in the developing world.

International Energy Agency, "Energy Efficiency Governance," 2010.

### Why is Change Necessary?

The shift toward designing more sustainable buildings is driven by multiple factors. Many of these factors are related to the ways in which we consume our planet's resources and the negative effects of our over-consumption; but some of them are about the positive attributes of sustainable buildings such as access to daylight, higher indoor air quality, great views and green space.

All of this consumption means that competition for our limited and non-renewable natural resources (for example our ever-decreasing supply of fossil fuels) is increasing, and the price of these commodities is being steadily driven up as a result.[1]

It is a very different world today than when the first multi-storey buildings were built in the 19th century. In today's era of skyscrapers and sprawling buildings, it takes more energy than ever to maintain comfortable air temperatures, keep hot and cold water available throughout each building, and to run the moving parts such as fans, pumps and elevators.

Worse, energy consumption by the building sector is currently projected to increase even more in coming years. The U.S. Energy Information Administration predicts that building sector energy consumption will grow faster than that of both industry and transportation. By 2030, it's predicted that total building sector energy consumption will increase by 5.85 Quadrillion British Thermal Units[2].

### The Effects of Greenhouse Gas Emissions

The effects of Greenhouse Gas (GHG) emissions, mainly from the burning of fossil fuels, can be seen and felt in every part of the planet. Average temperatures are rising, affecting everything from sea levels to food production. In the 21st century, GHGs are the most significant type of airborne pollutants that we must focus on because of their far-reaching, long-term impacts. As buildings generate almost half of all GHG emissions, it is imperative to use more sustainable building technologies to collectively lower our carbon footprint[3].

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1. Robert L. Hirsch, "The Inevitable Peaking of World Oil Production," The Atlantic Council of the United States, October 2005
2. Architecture2030.org
3. Nicholas Stern, *The Economics of Climate Change* (Cambridge; Cambridge University Press, 2007)

Why such a focus on our carbon footprint? Reduction in carbon footprint equals efficiency and efficiency equals lower impacts over time, meaning that we can then avoid paying great sums of money to retroactively correct the impact. If we take a proactive approach to managing and minimizing what we create, we pay forward on the investment. The "footprint" metaphor communicates that our responsibility to lower consumption is an individual effort, netting a collective result.

## Government Response

Faced with the situation of dwindling resources and the negative effects of over-consumption, governments around the world are grappling with how best to respond. It's become clear that retrofitting the existing building stock and ensuring that all new buildings are high performance buildings are the two most effective approaches for governments to curb energy consumption and greenhouse gas emissions. They are now implementing a variety of diverse policies and programs in different parts of the world that are all similarly aimed towards the goal of driving improvement in energy efficiency.

### Legislative and Regulatory Changes

A variety of policy types and programs are driving change in building design.

**Incentives**

Incentive programs are being established by governments around the world that provide funding to those who are willing to incorporate existing or new technologies that will help lower a building's carbon footprint and improve its performance and interior environment.

Market-based incentives help to correct for under investment in energy efficiency, instead placing an emphasis on what is optimal for society. They can

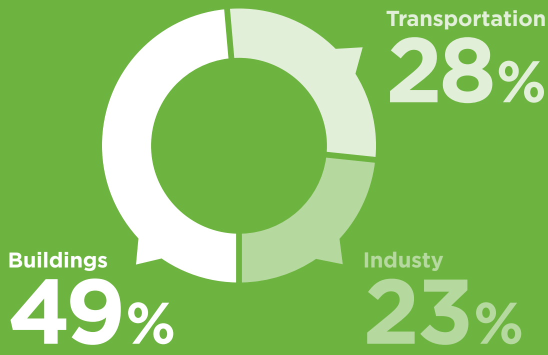
## Buildings represent nearly 40% of final energy used globally.

However, large and attractive opportunities exist to reduce buildings' energy use at a lower societal cost and a higher return than in other sectors.

World Business Council for Sustainable Development, Energy Efficiency in Buildings

### USA ENERGY CONSUMPTION BY SECTOR

**U.S. Energy Information Administration, 2009**



**By taking a new approach to development and using a building as an instrument for sustainability, resiliency, and wellbeing,** we can reverse the building sector's impact on the environment and foster vibrant, inclusive, cities.

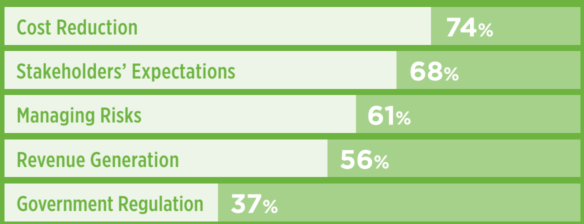
"Building the Green Economy from the Ground Up", U.S. Green Building Council, October 2011

include subsidies, taxes and cap-and-trade systems.

**Performance-based regulations**
These regulations ensure that all parties in the creation of a building work towards the same targets. Regulations include stricter building codes, resource standards put forward by regulatory bodies, and making changes to ensure that utilities are not only rewarded for selling a higher volume of energy.

### THE MOST IMPORTANT FACTORS DRIVING SUSTAINABILITY AGENDAS IN BUSINESS:

**Source: "Six Growing Trends in Corporate Sustainability"**, survey by Earnst and Young in cooperation with Greenbiz Group. 2012.




Building codes and regulations are also becoming stricter. In Europe for example, the EU Energy Performance of Buildings Directive (EPBD) will require all new commercial and residential buildings to achieve "nearly zero energy" design for all new construction starting in 2020.[4]

In Canada, examples include a supplementary standard (SB-10) being revised in the Ontario Building Code in 2012 which sets out more stringent requirements for energy efficiency.

In China, the Ministry of Finance published a directive in May 2011 setting out the energy efficiency standards that all newly constructed government buildings in China must meet. Many provinces and municipalities are also retrofitting their government buildings.

The Chinese government also encourages green design by providing funding for demonstration projects, both in the form of upfront funding and an award after completion. Developers sometimes consider demonstration projects more profitable

4. "EU Energy Policy for Buildings After the Recast," European Commission Directorate-General for Energy and Transport, 2009

**AN ESTIMATED**

# 70%

## of all people on earth will be living in urban areas by 2050

Population Reference Bureau: www.prb.org

than regular projects because of the availability of government funding[5].

Rural-urban migration is also expected to keep growing as more people flock to cities in search of better employment opportunities. An estimated 70% of all people on earth will be living in urban areas by 2050[6].

This shift towards higher density, urban living could be beneficial in terms of providing more efficient services to larger numbers of people – but only if we re-invent our building stock and construction practices to reduce energy use and make buildings better able to work in harmony with their inhabitants and with each other[7].

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5. "Green Buildings in China: Conception, Codes and Certification," The Institute for Building Efficiency, September 2011
6. Population Reference Bureau: www.prb.org
7. Stewart Brand, *Whole Earth Discipline* (Viking-Penguin, 2009)

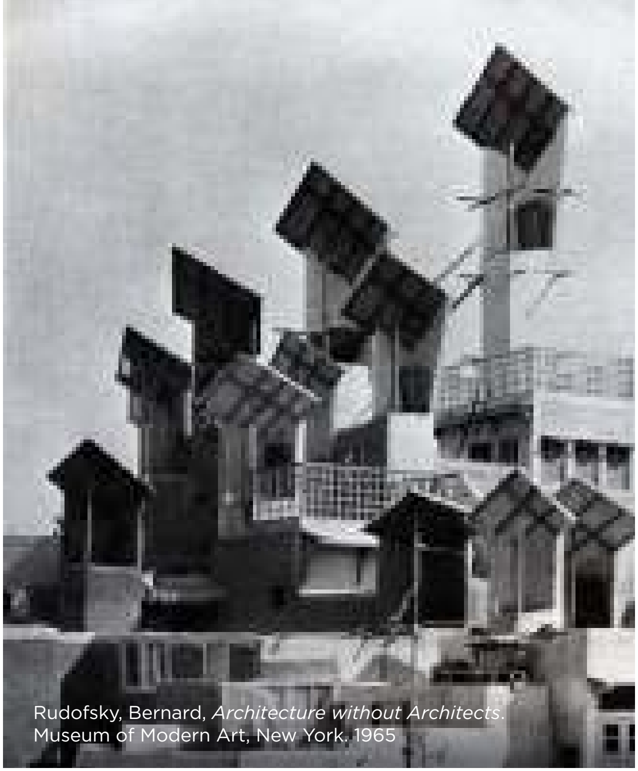
Photo credit: Amphotora Images

# What Makes a Building “Green”?

Green buildings are shaped by both their physical and social elements. How a building is designed and constructed is important, but more important is the way in which people live with the building, and how they interact with it and each other.

It can be a challenge to define exactly what makes a building green. In this section we will look at some of the most essential components. What’s common to all of these is how they improve the performance of the buildings, because a sustainable building is a results-driven building.

**Heritage Mountain Middle School, Anmore, Canada.** Recipient of Canadian Architect Award of Excellence 2011



Rudofsky, Bernard, *Architecture without Architects*. Museum of Modern Art, New York. 1965

Building Research Establishment Low Energy Office, England: main elevation with louvres open

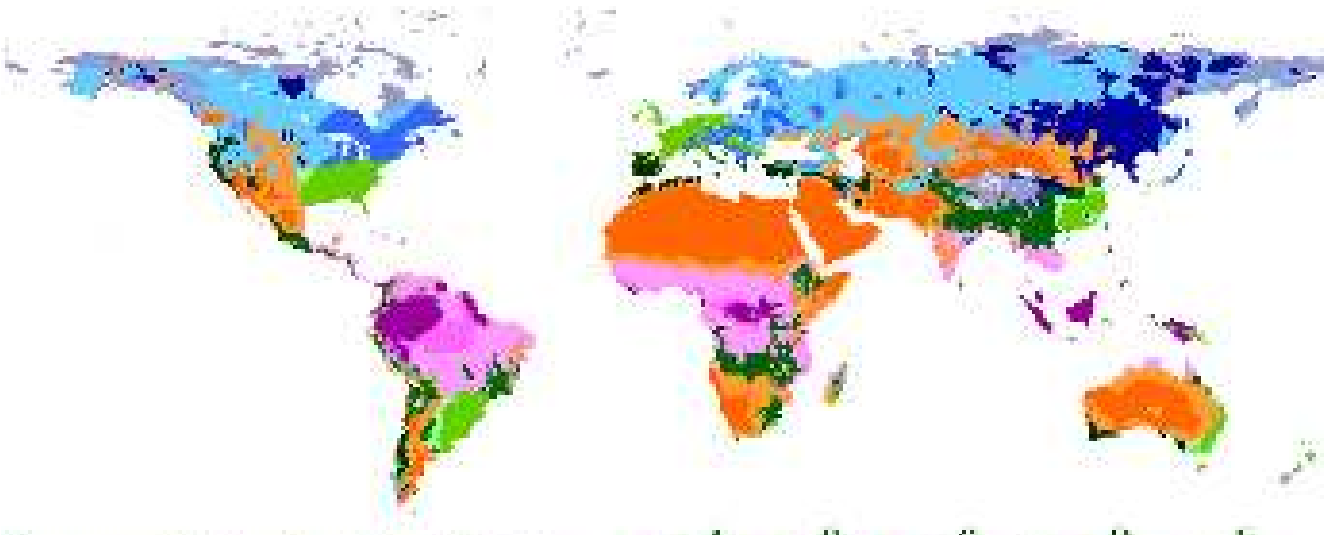
**Smart architecture is sometimes surprisingly obvious.** The solutions are simple, but elegant.

Ed van Hinte, *Smart Architecture* (010 Publishers, 2003)

The challenge of defining what makes a building green in the absence of any universal standard continues to hamper the development of sustainable design. However, it is imperative that businesses have access to the information they need to make their investment decisions, and certification rating tools have developed as very valuable ways to measure a project's sustainability and therefore return on investment. Some of the key rating tools being used today are: LEED® (International, Canada, and US versions), BRE (in Europe, Canada and China), the Energy Star® certification program, Green Mark (Singapore), Estidama Pearl Rating System (UAE), Three Star (China), and Green Star (Australia and South Africa).

Although we have not yet reached a point of consensus on what makes a building green, we have amassed a great deal of wisdom over years of working with new and existing buildings to maximize their sustainability.

One lesson has become particularly clear in optimal green design, and that is that often we need to take a "forward to the past" approach. The biggest gains in energy reduction are realized in the simplest ways, by thoughtfully employing passive energy strategies and




**Koeppen's Climate Classification**

FAO - SDRN - Agrometeorology Group - 1997

working in a way that's coordinated to bring the best ideas together at the best times.

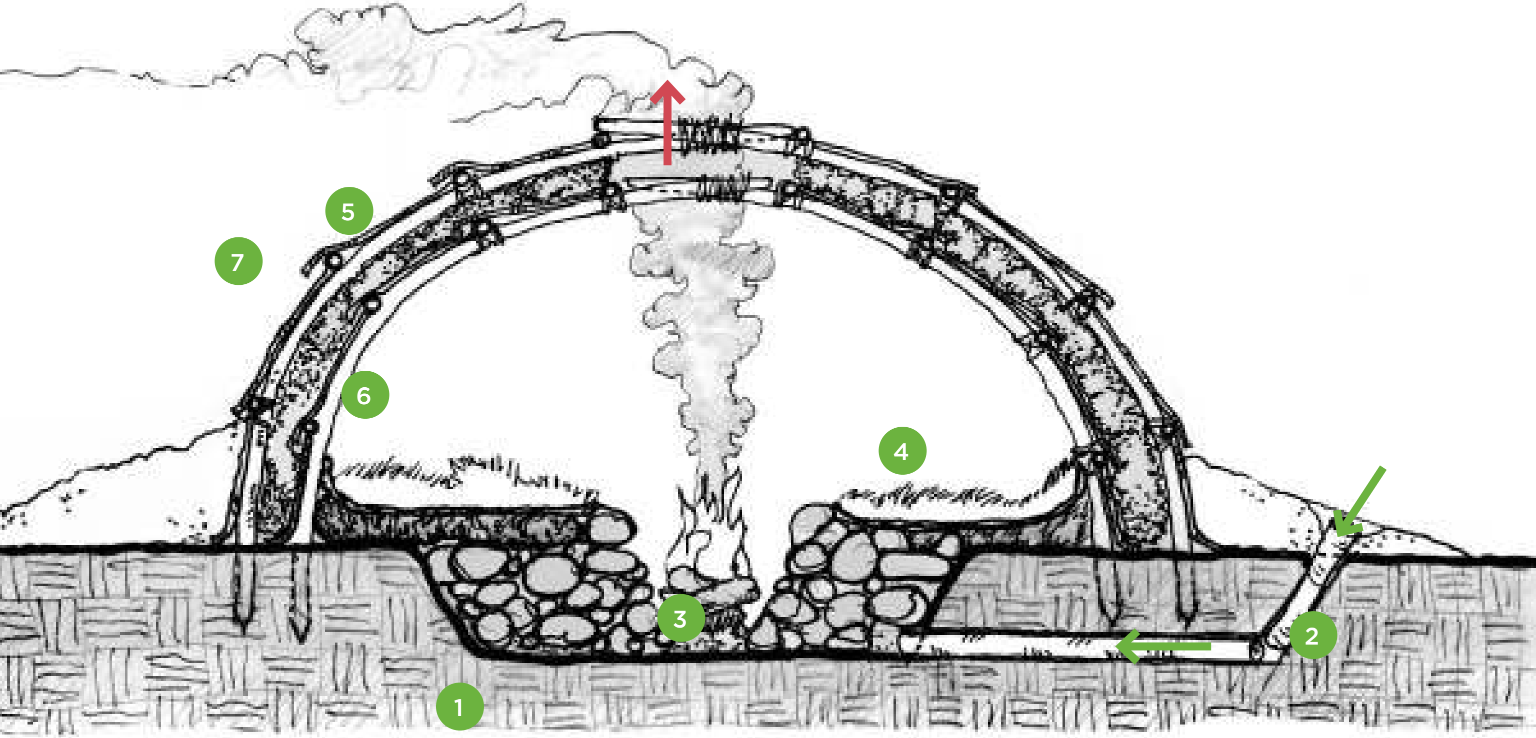
## Climatology

The climate is the way by which the earth moves energy around the globe; and this can be used to the advantage of buildings in microclimatic situations. The latent energy flows of the building site can afford enormous benefit to the energy management strategy of the sustainable designer. The reality remains that the study of weather patterns has been the purview of historical and vernacular building design for centuries past; and only since our recent collective cultural and technological exploitation of easily convertible energy has such design strategies fallen unemployed. The deep engagement with high performance design mandates that climatology reassert itself within the cannon of architectural methodology.

## Buildings that Achieve More with Less

High performance buildings achieve more with less. They seek to give us greater amenity, comfort and utility along with the reduced use of energy, water and material. They endeavour to provide greater access to light, fresh air, and better ergonomics with less energy consumed and less water wasted.

High performance buildings are able to take concept and design and use the best and most innovative technologies to implement them. However, the right solution is not always the highest technology solution. Advanced design modelling and analysis often help the designer select the simplest, most passive strategies to attain high comfort and low impact.




## A High Concept, Low Tech Construction

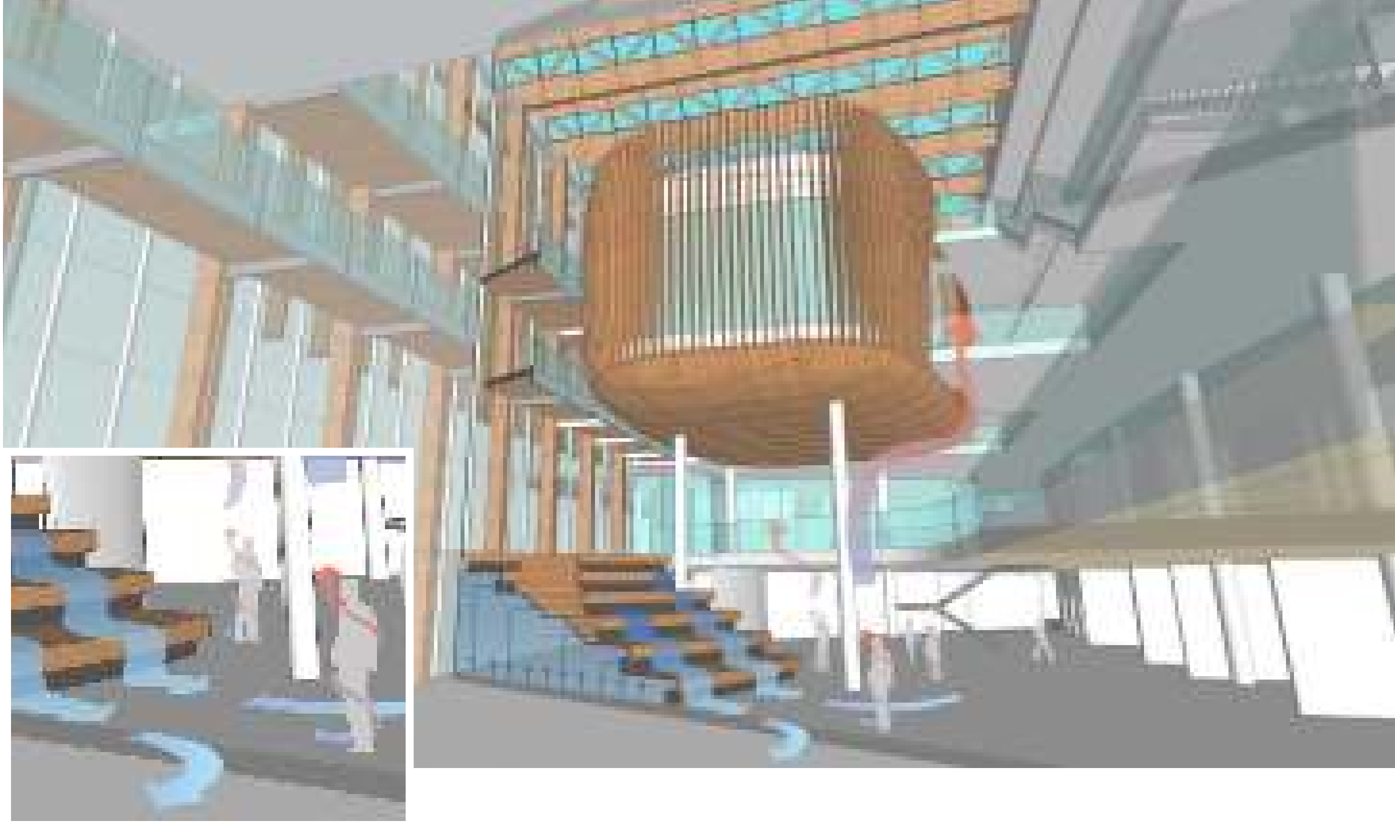
An in-depth look at the wig-wam.

**Above:** High concept does not necessarily mean high-tech. It is a judicious combination of proven historical methods (low-tech) with the appropriate modern systems. The building science behind the wig-wam is significant: it includes cavity wall construction (double-wall), insulation (moss-packed cavity), efficient combustion for furnace (dedicated ventilation tube for the fire pit), thermal mass and delayed release of heat (river-rock floor), imbricated siding (lapped bark watershed), locally-sourced and biodegradable materials. Many historical buildings can be seen as the first examples of 'green' design because they were forced to optimize their configuration and materials to maximize their performance with little to no artificial energy conversion. Comfort had to be garnered from passive measures. Combining these passive strategies with our new high-efficiency systems will enhance our comfort, our performance, and produce buildings that are 'Light Tech'. (Klaus Daniels, *High Tech, Low Tech, Light Tech*. Birkhauser, 2004.)

**The wig-wam (8-12 ft in diameter) consists of :**

1. **Main frame** built with 12-15 poles, 2 ft apart. Maple is used but ironwood is also present
2. **Birchbark cylinder** for air supply - better combustion
3. **The fire** is built in a recess in the rocks, which radiate stored heat after the fire dies out
4. **Flooring:** cedar/balsam boughs covered with rush mats, furs and rugs
5. **Outer frame** built 6" from inner frame. The space is stuffed with swamp moss - for insulation
6. **Inner frame** has birchbark- "wiigwass"-tied to it
7. **Covering** is elm, cedar or basswood bark - shingled for shedding water

Sources:
Nabokov, Peter & Robert Eastern, *Native American Architecture* (New York: Oxford University Press, 1989.)
Ted Kesik, University of Toronto, ALTD, 2008



As described by Steven V. Szokolay in *Introduction to Architectural Science: The Basis for Sustainable Design*, Designers strive to:

1. Examine the given conditions (site conditions, climate, daylight, noise);
2. Establish the limits of desirable or acceptable conditions (temperature, lighting, acceptable noise levels);
3. Attempt to control these variables (heat, light and sound) by passive means as far as practicable; and then
4. Provide for energy-based services (heating, cooling, electric lighting, amplification or masking of sound) only for the residual needs.[8]

8. Szokolay, Steven V., *Introduction to Architectural Science: The Basis for Sustainable Design* (Elsevier, 2007)

**Above:** Displacement Ventilation - University of British Columbia Student Union Building, Vancouver, British Columbia, Canada. High performance design means low energy consumption, which often means low power density systems such as displacement ventilation (DV). This diagram shows displacement ventilation at the UBC Student Union Building (SUB). Integrated design process means more integrated solutions. These systems provide excellent comfort and indoor air quality for low energy input and require that the loads estimated for the building systems performance are highly optimized. Very close coordination between all consultants within the design team is essential such that the loads are closely defined. The integrated design process allows for this close alignment. This is necessary because the slight change of a window specification can increase the cooling load of the HVAC significantly, or the unexpected redirection of ductwork can increase the pressure drop thereby requiring fan upsizing – both resulting in the DV malfunctioning.

**Queen's University - Beamish-Munro Hall**, **Kingston, Canada.**
4 Green Leafs rating

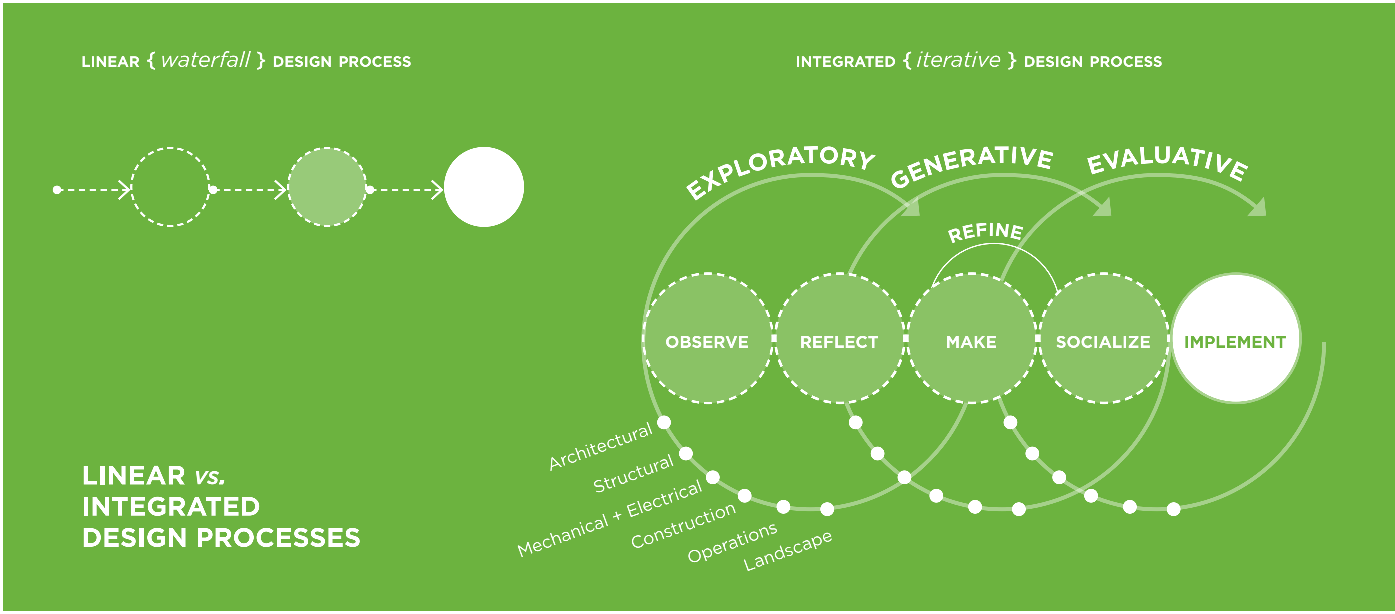
## Buildings as Educators and Behaviour Changers

There is another type of passive energy-reduction strategy at play in many of the best green buildings, and this is one involving the people who occupy it.

High performance buildings create elements that remind people of their involvement and responsibility to create their own improved environment that collectively results in value for all. Our built structures and landscapes can be designed to provide benefits of abundant daylight and temperate fresh air through operable windows and increased greenery both inside and out. This results in increased air movement and exchange rates and decreased $CO_2$ thus better filtering the air and reducing the build-up of heat and stagnant humidity or water caused by low exchanges of air movement and hard surfaces. For example, using individual task lighting and plug loads and most importantly turning equipment off when not required, as well as keeping daylight and views accessible, improves the environment for all. Evidence-based design in healthcare has proven that patients with access to natural daylight and views of nature recover more quickly.

## Integrated Design Process

High performance buildings differ significantly from other buildings in that the design process for creating them is shaped around the concept of integration. They're not just made with different materials and systems, they're made through a process that is fundamentally different from conventional design. This process recognizes that buildings consist of interdependent systems, each of which affects the other. high performance buildings typically use an integrated design process (IDP), which involves the entire project



team working throughout all components of the project to optimize the building for sustainability and performance.

For example, the type of windows selected has an effect on the heating capacity required because of the collection of passive solar heat, and it also affects the need for artificial lighting, which in turn affects the amount of cooling that will be required. Rather than a linear process of one party handing off to the next when their portion is complete, with the integrated design approach, communication between all building disciplines begins at the earliest phases of design and therefore all partners are able to weave their work together in the most efficient way possible.[9]

B+H uses Building Information Modelling (BIM) to support the Integrated Design Process and collect information about a building as it is being designed and built, calculating energy loads as the design is changed, and allowing a mutual platform for all consultants. This helps us to create a living document which looks at a building over time, tracking the lifecycle and components of the building.

## The Importance of Information Management

Establishing a rich and well-organized flow of information is a crucial step early in the design process. Sustainable designers use the most advanced measures of gathering and manipulating data such that their buildings respond with the greatest effect for least resource.[10]

For example, by analysing data that helps us understand the innate energy flows of the unique situation of the building project site, designers are able to tap into the most immediate sources of 'free energy'. In addition to understanding the external energy flow of the building, sustainable designers must gather data that will help us understand how energy is moved around within the building. Every building is unique, and the way energy flows is partly determined by what the building is used for. Air and water and people move around in a hospital in a radically different way than in a residential condominium, for example. Coming to terms with the differences - and hence the opportunities - of various building types makes for another layer of information to mine for optimizing energy flows and building performance.

Once the project is constructed, the true life of the building begins. Monitoring this emergent life and verifying its performance is the ultimate layer of information that sustainable designers must understand. Buildings and building systems that manage this layer of information well offer us the greatest opportunity for optimized performance. Finally all the knowledge that formulated the design is now empirical and can be readily measured, tested and analyzed.

The feedback and information can now help residents to understand and modify their behaviour towards more sustainable practices, which is the ultimate goal[11]. Buildings that measure and return feedback to allow users to see the results of their behavior, and how their consumption compares to others', help to create a culture of sustainability.

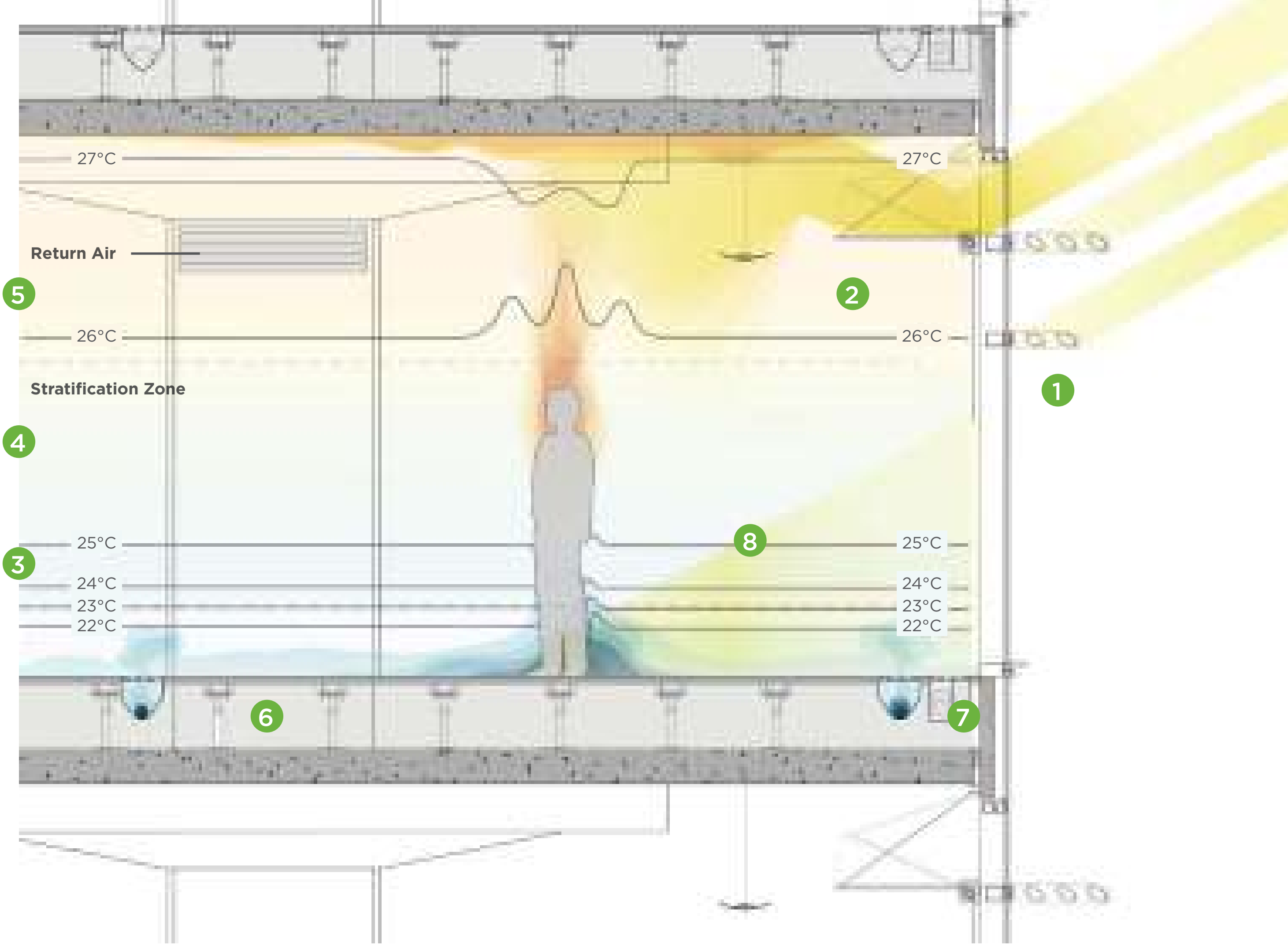
9. "A Business case for Green Buildings in Canada", Canada Green Building Council, March 2005
10. Klaus Daniels, *Low Tech, Light Tech, High Tech*, (Birkhauser, 1998)
11. Manfred Hegger, *Energy Manual*, (Birkhauser, 2004)

Photo credit: Kevan Davis

The communication of energy information can be a social experience, and people are finding creative ways of going about it.

## In 2011, households on Tidy Street, in Brighton, UK, volunteered to participate in a project in which they would take daily electricity meter readings and enter these into a website set up for the project.

The street's energy use data was compared to city, national and international averages. A local artist then painted a graph showing the results in the middle of the road in front of the houses. The street infographic caused both the street's residents and passersby to reflect on their electricity use and to start to identify which devices in their homes were using the most power, and when. The result was an **average 15% usage reduction**, with some households cutting energy usage by **as much as 30%**.




## Integrated Systems - RBC Centre, Toronto

**Above:** Solar shading to prevent direct solar gain, combined with light shelf reflectors to spread daylight deeper with the floorplate. Under-floor services allow for exposed ceiling such that the thermal mass of the structure can help absorb heat and mediate thermal fluctuations. Displacement ventilation provides high levels of indoor air quality with minimal fan power, and high-efficiency lighting is driven by both occupancy and illumination sensors (operates only to 'top-up' beyond daylight, and only when space is occupied).

1. **Louvres diffuse sunlight**
2. **Light shelf deflects daylight deep into office space**
3. **Fresh air enters at floor (17.5˚C)**
4. **Air heats up and rises (between 20˚C - 22˚C)**
5. **Hot, stale air is displaced to ceiling and into return vents**
6. **Reflow air**
7. **Fan coil system**
8. **Isotherms at occupant boundary zone – the heat pump that drives the displacement effect**


## A Detailed Look at Envelope Design

The UBC Student Union Building (SUB), Vancouver, Canada, targeting LEED® platinum, under construction.

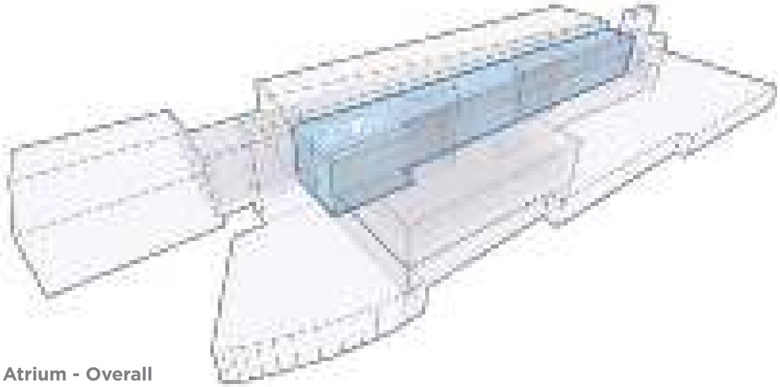
**Left:** The envelope design is an essential system contributing to the total performance of the facility. Estimated energy intensity of less than 75ekW/m2/annum can only be accomplished because the exterior loads are super-well controlled with (among other elements) R30 (effective) walls and fibreglass and triple-glazed windows. The low-density thermo-active structure is only feasible if comfort will not be jeopardized by a poor (or even average) envelope. High thermal resistance and airtightness of the SUB assemblies will ensure the radiant systems can operate optimally.

1. **Mineral fibre insulation**
2. **Foam filled cavity**
3. **Rainscreened fibre reinforced concrete cladding**
4. **Triple glazing**
    - Argon filled
    - Double low-e coating
    - Thermal spacers
5. **Exposed concrete with high content S.C.M. mix**
6. **Transluscent daylighting panel**
7. **Low density heating and cooling thermo-active structure**

## General Principles and Methods of Building Massing: Atria

Microsoft Zizhu Campus, Shanghai, China - Atrium/ Daylighting

**Above:** The general deployment of the building volumes and building massing can drastically affect overall building performance. The employment of atria can positively influence many factors including: the extensive distribution of natural daylight, the allowance of HVAC buffer zones to absorb thermal fluctuations and the accommodation of interior plantings for $CO_2$ reduction, aroma of living plants and calming views of nature.

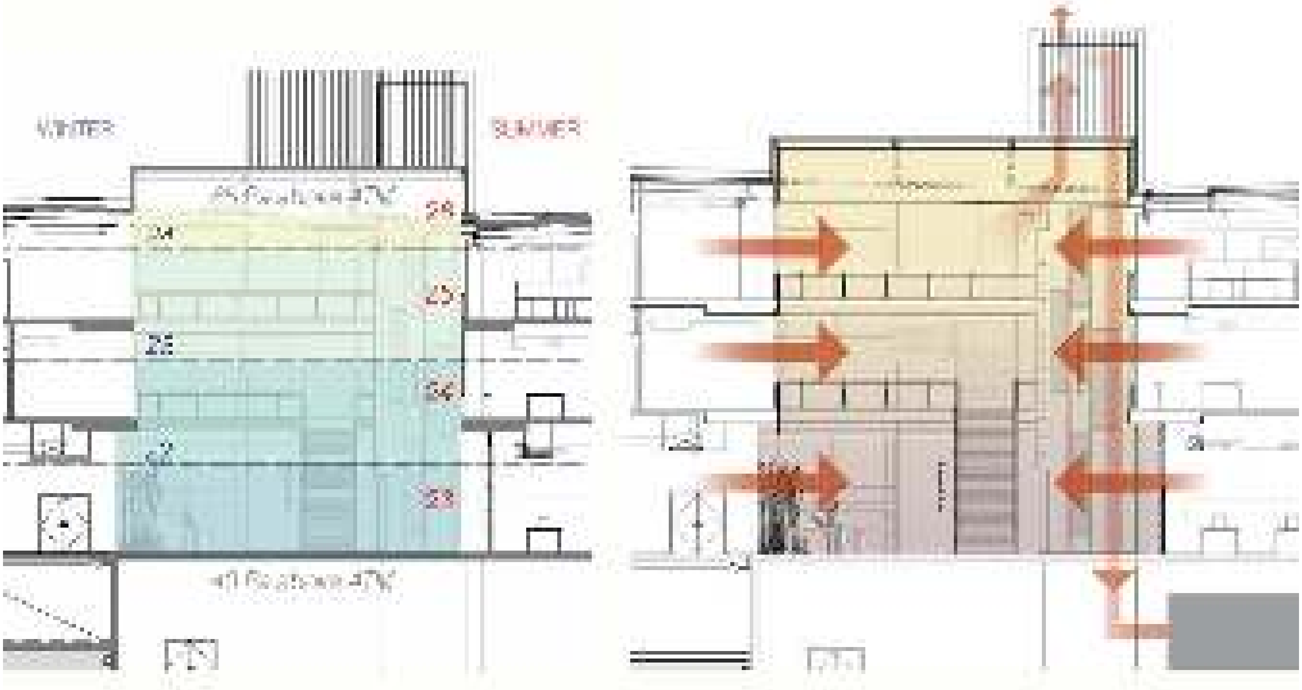


Atrium - Overall

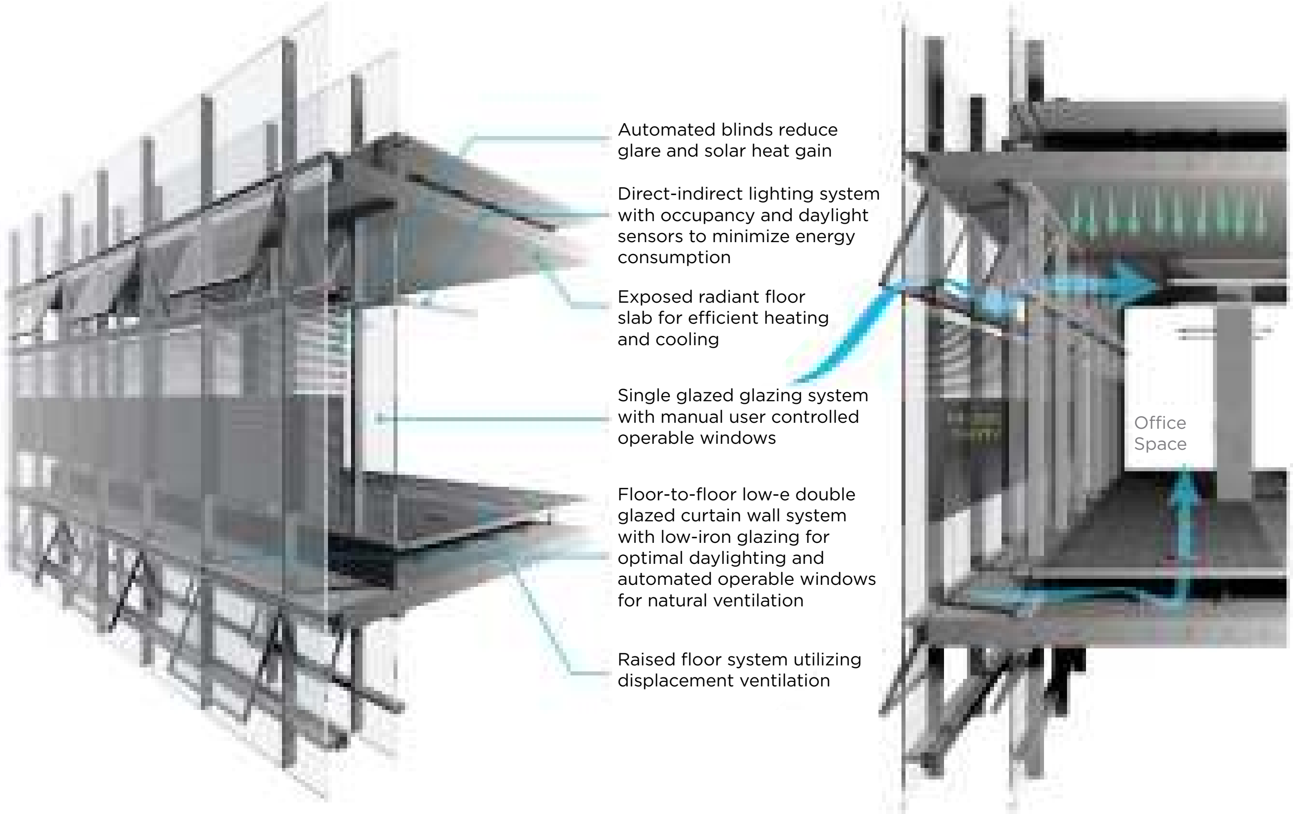
## General Principles and Methods of Building Massing: Atria

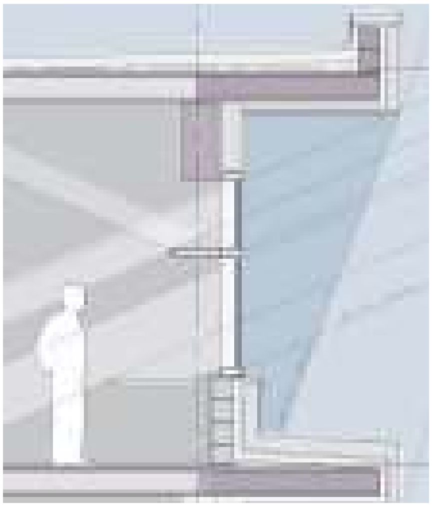
University of Windsor, Ed Lumley Centre for Engineering Innovation, Windsor, Canda.
Target: LEED® Gold certification.

**Left and below:** The atrium operates as a large relief air plenum that is passively exhausted. The temperature and humidity is allowed to fluctuate beyond adjacent laboratory zone levels so as to operate as a buffer zone. 5-8% energy savings is expected solely due to lower air volumes.




Atrium - Relief Air Plenum



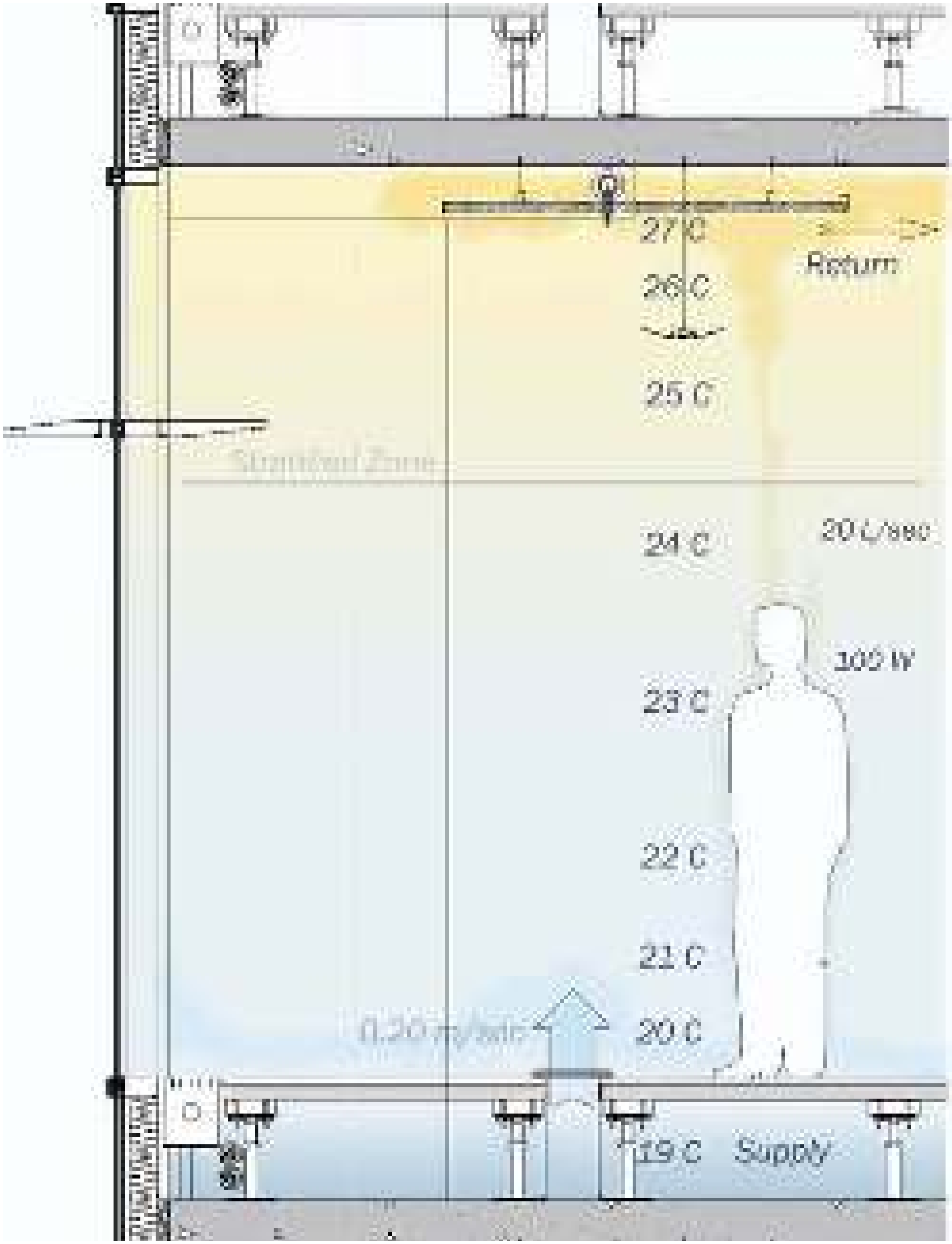



## Building Envelope

Theoretical Building Sections

**Above:** Ultra-high performance glazing for high rise building: utilizing triple glazing will drastically improve window performance, and employing twin leaf versions will allow for preheating and passive ventilation opportunities to increase performance further. Note thermo-active structure.

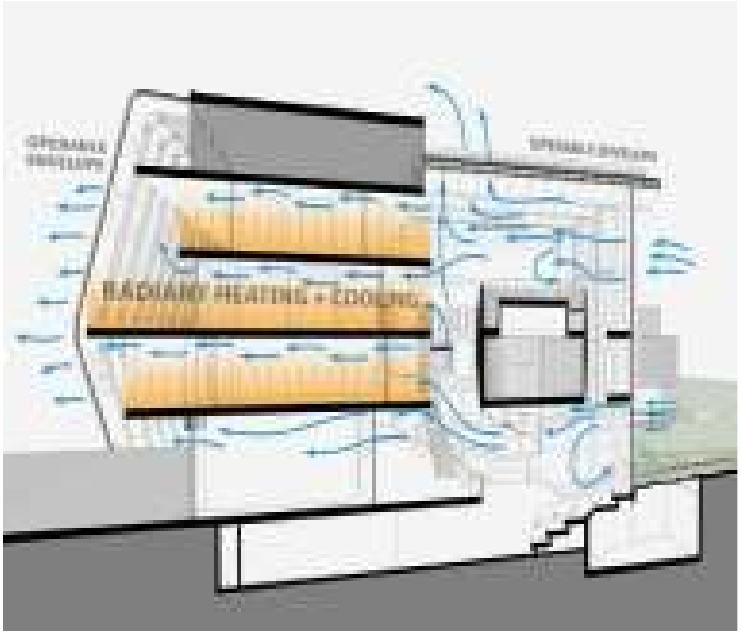
**Right:** Fenestration Shading: Building elements can be configured to shade unwanted solar radiation in the summer months, while allowing light to penetrate in the winter months.




## High Performance Mechanical Systems

Low Energy Ventilation - Archives of Ontario (Study) at York University, Toronto Canada

**Left:** High performance buildings employ highly efficient mechanical systems to ensure maximum comfort for minimal energy consumption. One such sub-system is displacement ventilation. This technology provides for low energy input but very high ventilation effectiveness. The system ‘piggy-backs’ the natural thermal plumes created by people and equipment in order to transport fresh air from the supply diffuser to the occupied zone. This fresh air is dedicated outside air, which means it is not mixed with the already spent air, so the occupants receive undiluted ventilation. The supply air moves along the lower levels to find people (thermal plumes) and then uses the heat to generate buoyancy pushing the stale air above the occupied zone.




## Advanced Siting, Building Configuration & Low-Energy Systems: Passive Ventilation

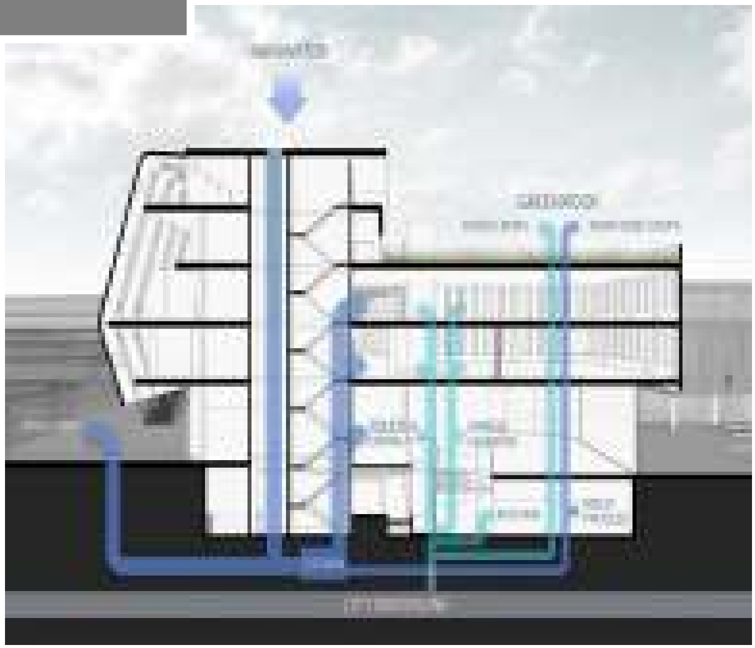
Passive Ventilation - UBC Student Union Building, Vancouver, Canada

**Left:** High performance buildings often rely upon passive measures to reduce energy consumption. The key to reliable implementation and operation of this design strategy is advanced modelling of microclimatic effects. Passive ventilation can be an enormous benefit to users and operators as 1) the occupants can control their ventilation whilst 2) the operators save on energy consumption. Not only will indoor air quality improve (predicated on good modelling and design) but fan power and mechanical ventilation can be substantially down-sized further reducing mechanical servicing and maintenance.

## Water Management

Water Management - UBC Student Union Building

**Right:** Our built environment is changing the hydrology of our planet at increasing rates. This affects the access to potable water aquifers and surcharges for an already overburdened infrastructure (existing storm and sewer systems). Water can be recycled for many purposes within buildings, especially for irrigation and sewage conveyance. At the UBC SUB, potable water from the municipal supply is solely used for human consumption and food crop irrigation. Rainwater is used to flush toilets, water landscaping and process water use.

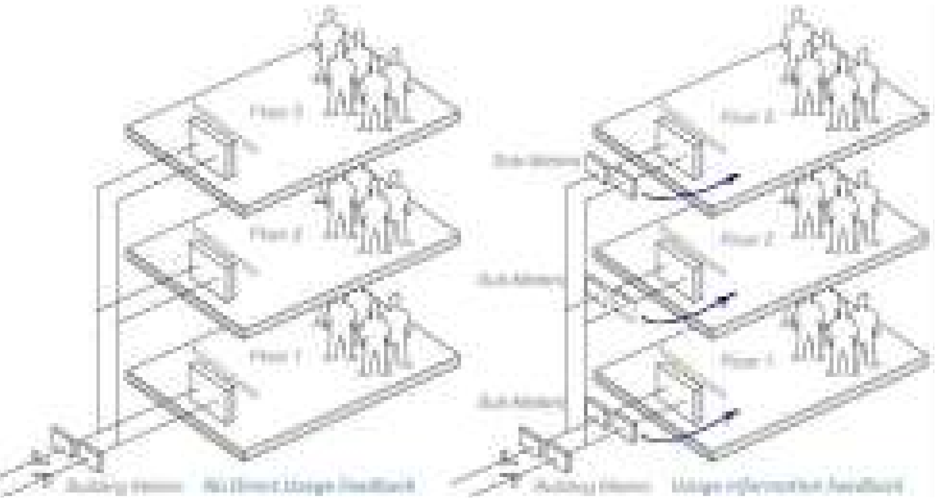


**University of British Columbia - Institute for Computing, Information and Cognitive Systems, Vancouver, Canada.**
This project employs a variety of energy efficiency measures (designed to LEED® silver specifications), notably displacement ventilation and radiant heating & cooling
(photo credit: Richard Johnson)

# Measuring Performance

In order to manage energy consumption and emissions, we must have the technology and processes in place to measure them.

**Photovolatic cells in a solar panel** (photo credit: Martin Vonka)



## Sub-Metering and Benchmarking

**Left:** Providing a level of granularity regarding sub-metering can allow the building to indicate to individual tenants their energy consumption. This may, or may not, influence change towards energy reduction. If the tenants are given their measured consumption in conjunction with the benchmark average tenant consumption, then this tends to encourage change towards reduction. All things being equal, people tend towards consuming just below (at least) the average rate, in order to feel they contribute to positive change.

## Life Cycle Costing

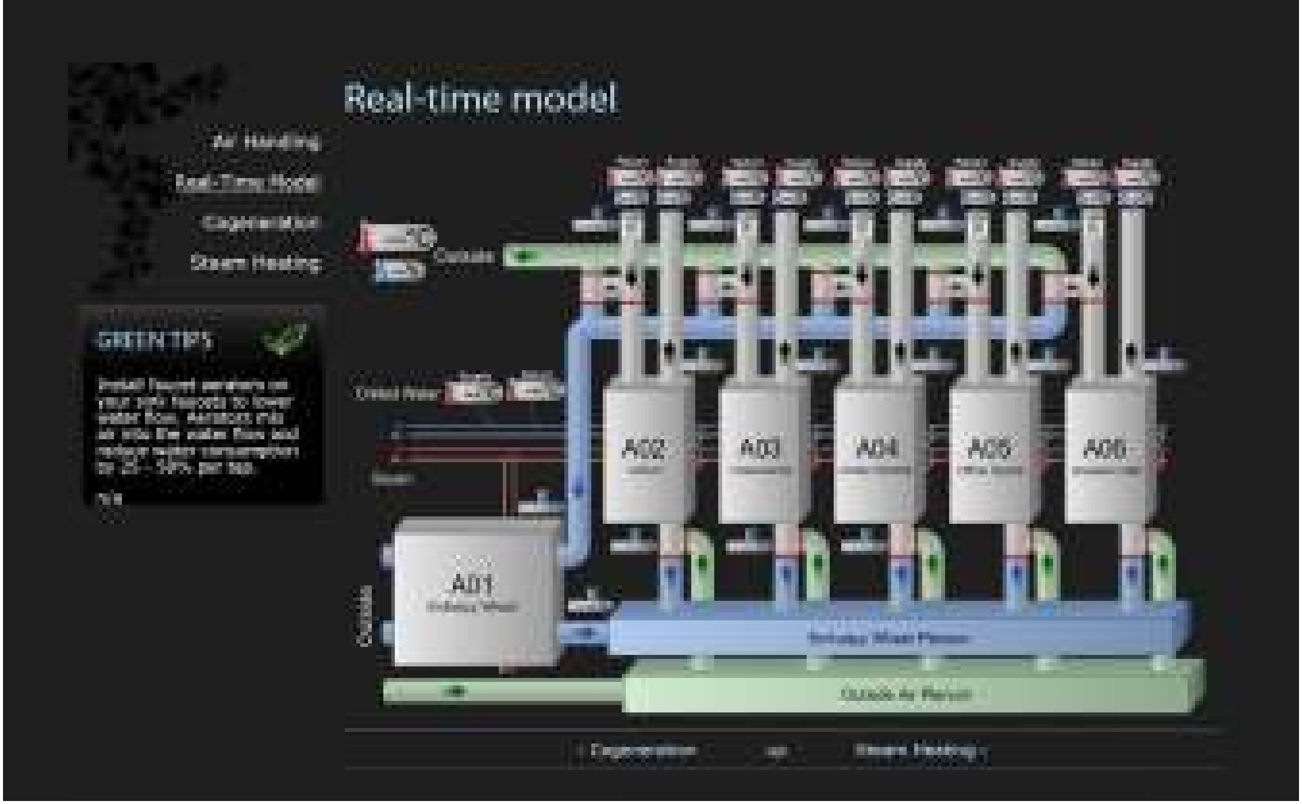
Sustainability means ensuring buildings continue to function in efficient ways over their entire life cycle. The features that make up a building are now being chosen based on their long-term energy usage, so that building owners continue to see the cost reductions they expect from an efficient building. To target these efficiencies, extensive modelling is done at the outset to fully understand how the building will use its resources.

## Energy Modelling

Energy modelling is used to demonstrate building performance over time (for example, over the course of a year to look at seasonal changes). It's an invaluable tool to help designers ensure that the building and all of its systems will use energy in the most efficient ways possible.

The process begins with data. Energy data includes all of the factors that are measured and recorded that may affect energy usage, including direct energy use measures (such as electricity and gas) as well as indirect factors (such as building location, climate, size, user habits, and maintenance repair schedules). Through modelling, the data on these factors comes to life in a way that allows us to understand the cause of variable energy use and to set targets against which actual performance can be compared. Energy use targets establish a building's projected energy use by comparing it to a "baseline" model. The baseline model represents a building that is equipped to meet only the minimum energy standard of the current building code. The energy use data from the baseline model is compared against the energy data for the new design. Future energy modelling methodology will move towards absolute energy intensity targeting, and away from reference modelling.

To accomplish the task of understanding and optimizing building energy usage, designers use energy simulation software. Common applications include: DOE-2, eQuest and Energy-plus. Reports from the simulation software provide information on energy use, energy cost, and unmet load hours (the number of hours during a year when the building's systems are unable to maintain the set point temperatures for heating and/or cooling), for both the baseline and the design case energy models. It gives a robust picture, taking into account both the indirect and direct factors affecting the building's energy use.




## Innovations in Research and Learning

Queen's University ILC (Kingston, Canada) LIVE building interactive website.

**Above and right:** The buildings of the ILC are monitored and metred in order to provide a live stream of building performance data. Students and researchers can extract this data to understand the real-time operation of the building. In conjunction, they can observe web graphics that explain systems and building mechanics in an interactive manner. In such a way the laboratory becomes a learning tool in and of itself: an innovative tool to provide feedback and perform research and learning.


Using modelling software it is possible to adjust variables in one of the building's systems and observe the impact on other systems and on the total energy use in the building. In this way, the design team can identify the impacts of introducing energy conservation measures, and make the best choices for the building's performance over time. The purpose and usage of energy modelling is essential; and will only grow in importance.

**Toronto-Dominion Centre Revitalization, Toronto, Canada** (photo credit: Tom Arban)


**First Canadian Place Recladding Toronto, Canada** (photo credit: Tom Arban)

## Benchmarking

Benchmarking is important when designing new buildings; it is equally important as we analyze the ongoing performance of buildings over time.

In the initial design stage, comparing the energy use intensity of the design with benchmarks for buildings with similar characteristics can help in the selections of the most appropriate energy conservation measures. For example, ASHREA 90.1 is a standard that provides a benchmark for energy efficient designs, including the highest allowable energy-use intensity on a site. Other benchmarks are provided from data collected on existing buildings. EnergyStar has a website containing a large database of existing building energy metrics that can be used to gauge the energy use targets of the design with averages obtained from a large sample of existing buildings in the same class.

Buildings are also increasingly equipped with monitoring devices and control systems that provide real-time data about the actual energy use intensity of the building throughout the year. This information will be used to fine-tune building systems so that the design energy model and the actual energy use intensity align. For example, the B+H-designed Integrated Learning Centre at Queen's University has extensive measurement and verification systems in place, and the Centre for Engineering Innovation at the University of Windsor used similar systems.

Building owners are increasingly interested in having this information as they assess the life cycle cost of operating the building. Maintenance and replacement of building components can be approached in an informed way continually and routinely ensuring that the building is operating in its optimal capacity balancing operating costs, occupant comfort and targeted energy use. Furthermore, LEED® EB&OM mandates that buildings are re-certified and re-commissioned based on real accumulated data. This is a quickly-growing trend that fosters change for the better.

### Monthly Energy Use Dashboard

The Canada Green Building Council

**Left:** The Canada Green Building Council's GREEN UP program gives users visualization tools to help consolidate and benchmark their building's energy performance.

# The Business Case for High Performance Design

Building for performance is not new. Builders and buyers have always had an interest in keeping energy costs to a minimum. What's changing now is that a critical mass of evidence is in place showing the return on investment for "green" buildings. The proof is irrefutable: building for high performance makes good business sense.

**Brookfield Place - Allen Lambert Galleria, Toronto, ON.** Architect of Record: B+H, design architect: Santiago Calatrava (photo credit: LenScape Photography)

**Many in the building industry perceive green and/or LEED® certified buildings to be much more expensive than conventional buildings.** This perception has been the single largest obstacle to greater mainstream acceptance of green building design.

Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003.

Perhaps the single biggest challenge to building high performance buildings is the perception that they are much more expensive to build. Although the upfront costs of high performance buildings can be higher (but not always), when you consider the return on investment high performance buildings generate in their lifetime, it's clear that making buildings sustainable is an integral component of making a business sustainable. The editors of the State of Green Business 2012 report say that sustainable business "has become a normal, even mundane part of the business landscape... Addressing sustainability issues is no longer an optional, nice-to-do activity. It is an expectation".[12]

## The Cost and Challenges of Building Green

High performance buildings are usually assumed to be significantly more expensive than conventional buildings, but by how much more is often overestimated. For example, several reports have found that the cost of building to LEED® certification levels is far less than many in the industry perceive it to be. We have to take into account that the cost of going green will increase depending on the number and type of high performance technologies used, but that in general the costs are coming down over time. Architectural firms who have experience in the design and development are increasingly able to keep "green premium" costs at the lowest possible levels.[13]

There are several challenges that have made determining the exact cost of high performance buildings difficult.

**Some key barriers include:**

- Lack of life cycle costing, meaning looking at the costs and benefits over the life of a particular product, technology or system.[14] Life cycle costing looks at costs and benefits over the life of a particular product, technology or system. It is necessary to look at the performance value high performance buildings add, rather than just immediate cost.[15]
- Many developers keep cost information proprietary, and do not price out individual green items as compared to the conventional alternative.

12. Joel Makower et al, "The State of Green Business 2012", GreenBiz Group, January 2012

13, 14. Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003

15. "A Business Case for Green Building in Canada," The Canada Green Building Council, 2005

- The first high performance building a client plans or that an architectural firm designs often involves significant learning curve costs, and design schedule problems such as late and costly change orders.[16]
- There is a shortage of data on conventional buildings to be able to compare and determine what the same building would cost as a high performance building.[17]
- The design process to better integrate components of sustainable buildings can take longer.
- Many benefits and ROI aren't immediately quantifiable – for example improved productivity, and enhanced tenant retention.

## Known Costs

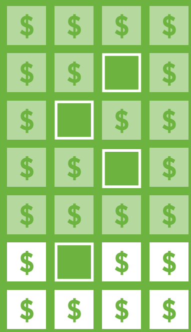
There are certain elements of performance-focused buildings that we know currently cost more. One example is commissioning. Commissioning is the process used to ensure that all building systems are tested and capable of being used according to the owner's defined requirements. Since performance-focused buildings must demonstrate that they provide better efficiency than conventional buildings, commissioning is very important and is required for LEED® certification. The costs of commissioning vary by building size, but are estimated to range from 2% to 4% for buildings costing less than $5 million, down to 0.5 % to 1% for buildings costing over $50 million.[18]

## The Benefits of High Performance Buildings

**These buildings:**

- Have lower energy consumption and emissions levels
- Are more attractive to occupants
- Are more competitive in the marketplace

16. Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003
17, 18. Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003



Energy cost represents **30%** of operating expenses in a typical U.S. building

(Fuerst 2009)

The net operating income per square foot of **ENERGY STAR® properties** was 5.9% higher than non-ENERGY STAR® properties

(Pivo 2008)

**A sale price premium of 13%**

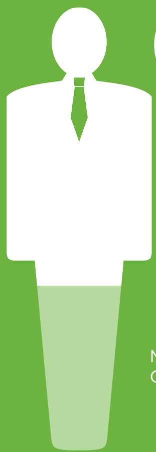
was found for ENERGY STAR and LEED® office buildings between 2007 and 2009.

(Eicholtz 2010)

## The CaGBC estimates a productivity gain of 2-10%

when moving from an average building to a green building with high quality natural light, exceptional ventilation and possibly user controls.

Green Building Asset Value: Trends and Data, 2011, Institute for Building Efficiency: an Initiative of Johnson Controls



**61%**

**of Executives** believe that sustainability will serve the financial performance of the company.

McGraw Hill Construction Report, 2011, Green Trends Driving Growth through 2015

## Lower Energy Consumption

The new generation of high performance buildings have technology in place to minimize total energy use, and also to switch between energy sources based on time of day energy costs. Combining innovation with flexibility is the key to having buildings that lower costs in addition to environmental impact. The data is mounting to support the cost reductions that can be seen when we lower consumption. For example, one study found that operating costs for LEED®-certified buildings are 8-9% lower than for non-LEED® buildings.[19] Another study, this one of government buildings in the U.S., found that sustainably designed buildings use 25% less energy, have 36% fewer $CO_2$ emissions and have 19% lower operational costs than the national average for comparable commercial buildings.[20]

A building that has been commissioned usually has resultant cost savings that more than pay for the cost of the commissioning because of the process results in the reduction of operations and maintenance costs. A cost reduction of 10% in operations and maintenance is equal to a savings of \$304 per person, or \$1.35/ft$^2$ per year.[21]

The results high performance buildings can deliver in lowering emissions are also very striking. A study by International Energy Agency (IEA) showed that global energy efficiency measures, when fully incorporated, are capable of delivering two-thirds of the energy-related $CO_2$ emissions reductions needed to achieve climate protection. Ensuring that new and existing building stock around the globe conforms to high standards of energy efficiency is will reduce emissions more than any other strategy[22].

19. "Green Buildings: A Niche Becomes Mainstream", Deutsche Bank Research, April 12, 2010
20. Green Building Performance, GSA Public Buildings Service, August 2011
21. Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003
22. International Energy Agency (IEA), World Energy Outlook, 2009

# Summary of US Green Office Value

Green Building Market and Impact Report, GreenBiz group, 2011

| STUDY CONDUCTED BY | PREMIUMS | | | | | |
|---|---|---|---|---|---|---|
| | RENTAL | | SALES PRICE | | VACANCY RATE | |
| | LEED® | ENERGY STAR® | LEED® | ENERGY STAR® | LEED® | ENERGY STAR® |
| Fuerst & McAllister (2011) | **5%** | **4%** | **25%** | **26%** | / | **1-3%** |
| Eicholtz et al (AER) | **5.2%** | **3.3%** | **11%** | **19%** | **15%** | **"Effective rent" 7% overall** |
| Eicholtz et al (RICS) | **5.8%** | **2.1%** | **11%** | **13%** | **"Effective rent" 6-7 % overall** | |
| Pivo & Fisher | **2.70%** | | **8.50%** | | / | |
| Wiley et al (2010) | **7-9%** | **15-17%** | **16-18%** | / | / | **10-11%** |
| Miller et al (2008) | **9%** | | / | | **2-4%** | |

## Occupancy Rates

### LEED® Buildings

**16-18%** higher occupancy than traditional buildings

### ENERGY STAR® Buildings

**10-11%** higher occupancy than traditional buildings

Wiley (2010)

## Strong Business Benefits Expected by Corporate America

| | |
|---|---|
| Customer retention & attraction | 73% |
| Drop in operating costs | 71% |
| Greater productivity | 62% |
| More tax incentives | 61% |
| Employee retention & recruitment | 39% |

McGraw Hill Construction Report, 2011,
Green Trends Driving Growth through 2015

**1 out of 3**
tenants will pay a premium
**for green renovated/ retrofitted space**

McGraw Hill Construction Report, 2011,
Green Trends Driving Growth through 2015

In terms of lowering energy consumption, high performance buildings are good for businesses and individuals, and also good for entire nations. By incorporating renewable resources into their design, these buildings aid in providing better energy security. Given that most countries are not blessed with infinite water, energy and materials resources, building sustainability into the plan means building security for the future, for buildings and for entire economies.

### More Attractive to Occupants

High performance buildings increase the productivity of their occupants. Although it's difficult to ascertain by exactly how much, the Canada Green Building Council has estimated "a productivity gain of between 2 and 10% when moving from an average building to a green building that incorporates high quality natural light, exceptional ventilation, and possibly user controls. For most office buildings, even the 2% gain will be sufficient to more than compensate for any extra costs associated with the design and construction of a green building."[23]

Additionally, a Lawrence Berkeley National Laboratory study found that U.S. businesses could save as much as $58 billion in lost sick time and an additional $200 billion in worker performance if improvements were made to indoor air quality.[24]

### Competitive Advantages

Businesses going green today have the opportunity to take advantage of new markets and to set themselves apart from the crowd by helping to define what the future of sustainable business looks like. Buyers and tenants already know that they want sustainable design and are now seeking out the buildings that apply these

23. "A Business Case for Green Building in Canada," The Canada Green Building Council, 2005
24. Greg Kats, *The Costs and Financial Benefits of Green Buildings,* October 2003

principles in the most attractive and cost-efficient ways. Choosing high performance buildings not only boosts profits, it's one of the most impressive things a business can do to enhance its brand.

Investors are demanding enhanced accountability on environmental practices. They are worried that environmental standards violations will create operational, reputational and financial risk. One report found that shareholder proposals on environmental and social issues accounted for 40% of all shareholder resolutions in 2011, up from 30% in 2010."[25]

Concrete evidence is in place to support the competitive advantage that high performance buildings bring. Here are just a few examples of the results being shown:

- **Increased rental premiums:** A 2010 study saw rental premiums of 7-9% for ENERGY STAR buildings and a rental premium of 7-9% for LEED® buildings.[26]
- **Improved resale value:** One study showed that a sale price premium of 13% was found for ENERGY STAR and LEED® office buildings between 2007 and 2009.[27]
- **Higher occupancy rates:** Occupancy rates can be as much as 16-18% higher for LEED® certified buildings and 10-11% higher for ENERGY STAR certified buildings.[28]
- **Lower operating expenses:** One study showed that operating expenses were 30% lower for ENERGY STAR compared to non-ENERGY STAR buildings.[29]

25. "Leading Corporate Sustainability Issues in the 2012 Proxy Season," Ernst&Young LLP, 2012.
26. Wiley, J., Benefield, J., and Johnson, K. "Green Design and the market for Commercial Office Space." Journal of Real Estate Finance and Economics, Vol. 41, no. 2. 2010.
27. Eichholtz, P., Kok, N., and Quiqley, J. "The Economics of Green Building." Maastrict University and University of California – Berkeley, August 2010
28. "Driving Transformation to Energy Efficient Buildings", The Institute for Building Efficiency, June 2012
29. Miller, N., Spivey, J., Florance, A., "Does Green Pay Off?" Journal of Real Estate Portfolio Management, December 2008.

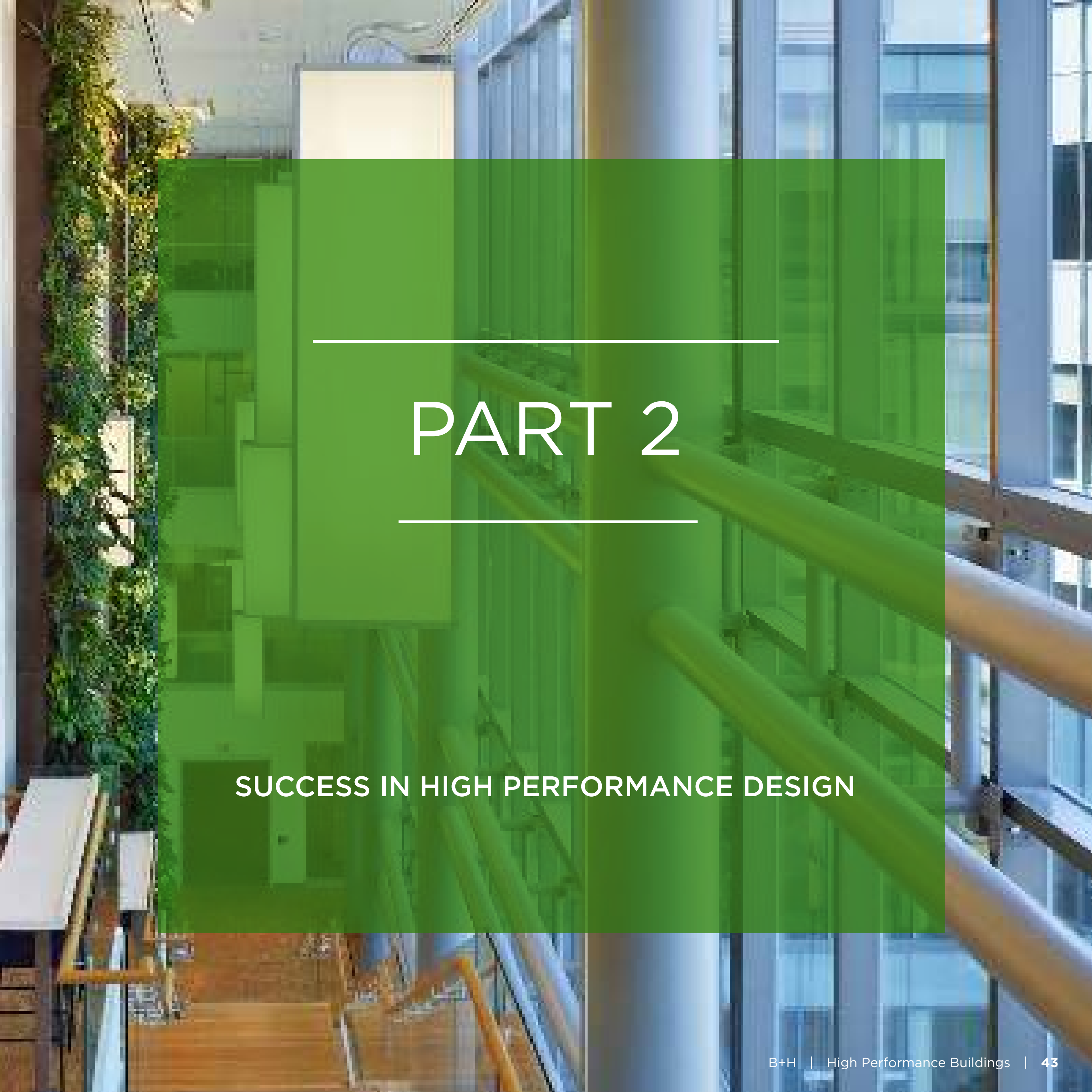
In past, decisions on whether or not to invest in sustainable buildings were based on the initial cost, plus an expectation of some amount of energy savings over time. When we take new approaches to examining costs, such as life cycle costing, and as new research in the field emerges, the overall picture becomes more clear. Green buildings often have decreased operating and maintenance costs, decreased environmental impact, greater occupant satisfaction and increased marketability.

Individuals and companies alike are recognizing the many benefits that high performance buildings give. The shift to sustainability is not only a progressive business strategy but also a consciousness change amongst the global population who live and interact with buildings every day.

**Where corporate sustainability once focused on compliance or reputational issues... it now has become strategic inside many companies**—it's as core to company operations as safety, quality, employee retention and customer satisfaction.

"Six growing trends in corporate sustainability," Ernst &Young, 2012

**Bell Canada Creekbank, Mississauga, Canada**
Main atrium with Bio-filter ventilation (photo credit: Tom Arban)



# PART 2

## SUCCESS IN HIGH PERFORMANCE DESIGN

# Surrey District Education Centre

**Location** Surrey, BC, Canada
**Size** 182,000 s.f. | 17,000 s.m.
**Client** School District #36
Photo Credit: Ema Peter Photography

**The Surrey District Education Centre has set an example for sustainable design for its surrounding community.** It has improved energy efficiency, air quality, daylighting, occupant health and comfort. It is expected to reduce the school district's carbon production by 62.5%, and provide a reduction in gas and electricity costs of 54.7%.

The Surrey District Education Centre is an integrated facility, designed to unify the school district's administrative offices under one roof. It houses 400 staff and provides a resource centre for students and their families. Further, it is intended as a means to a renewed relationship between the school district and the community as a whole.

The building design includes a geothermal district energy system, and features the largest installation to date of chilled beams in North America. The new facility reduces the school district's carbon footprint by 62.5%, before considering operational efficiencies by staff (such as the fact that travel time between offices has been eliminated). Energy demand and emissions will be monitored over time.

All occupied areas are lit with natural daylight with glare controls, and with workspaces oriented to take maximum advantage of the daylight. Great care has been taken with the selection of materials: all wood is certified by the Forest Stewardship Council (FSC), and none of the materials off-gas, produce particulates or support microbials.

It is the district's hope that productivity will increase as a result of the features of the new facility and the improvements in indoor environmental quality.

## Strategic Design

The Surrey School District was interested in reducing their carbon footprint through the consolidation of a number of outdated facilities into one new high performance building. They were also concerned with contributing to the community in a meaningful way, through public programs, art and social services that could be housed and accessed in the new building. Surrey is one of Canada's most multi- cultural communities and is home to many new immigrants.

Community outreach is key to the success of newcomers to the area, young and old. This project was helpful to the local economy in that it provided much needed jobs in the area.

## Community

In planning this project, the Surrey School District placed a high value on public spaces and amenities to benefit both the public and facility staff. Amenities include a rooftop patio, an employee lounge, bike storage, showers, fitness centre, cafeteria, public atrium with wireless, and a public courtyard. Local indigenous art enhances the space.

The facility is centrally located in the city hub and replaces numerous disconnected locations, resulting in a reduction of 4,100 hours of driving time annually for staff. It is accessible by public transit, and the school district encourages car pooling and car co-op.

## Site Ecology

The school district owns a large tract of land surrounding the District Education Centre. There is an area of protected forest to the east of the building bordering the edge of the site. The surfaces around the building are landscaped, and paving requirements for parking were kept to a minimum. All planting has low water requirements and is indigenous. Surface collection of water in bioswales, ditches and detention ponds is illegal in this community due to concerns about mosquito breeding and possibility of West Nile virus.

## Light and Air

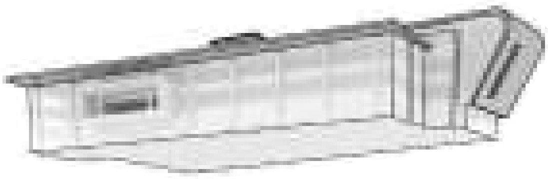
Carefully planned openings in the building envelope allow natural ventilation to flow from controlled points on the exterior through to the office spaces and naturally exhaust through the atrium at the high level and through internal chimneys. The shallow floor plates also contribute to a reduced building envelope


that reduces heat loss, controls unwanted solar heat collection, and results in reduced overall construction costs. The heavy timber beams used throughout function as both structure and glare control.

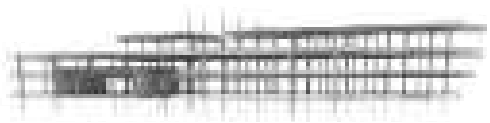
## Water Conservation

Water conservation is a concern for the school district and low water-usage fixtures and protocols were incorporated. The project reduced water use from 3,000,000 litres/year base case to 1,500,000 litres/year. This translates to about 3,700 litres/occupant/year or about 10 litres/day, about a 50% reduction on the base case. Since all plants have low water needs, there is no irrigation.

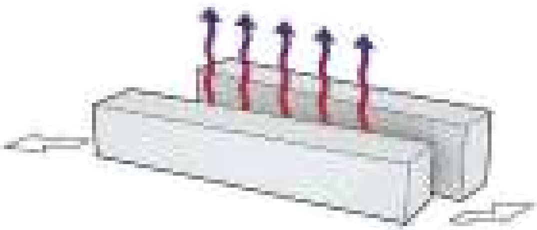
# An In-Depth Look at the Building



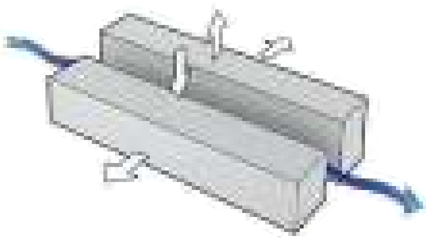
### 1. Skin
External walls are primarily glazed, which allows for increased daylighting all year round, along with the use of internal and external sun shades on the south decreasing solar heat gain in the summer. The curved roofs are clad in standing seam zinc.



### 2. Structure
The structure is a hybrid of local, sustainably harvested wood and high fly-ash concrete.



### 3. Skewed Plan
Skewing the mass creates a day-lit gathering space, provides space for circulation, allows for stack effect and maximizes afternoon sun on the north facade.



### 4. Shallow Floor Plates
Splitting the floorplates allows for the harvesting of daylight and views,and channels the westerly winds for passive ventilation.

### 5. Program
The program of this four storey building is split between administrative offices and conference facilities.


**Surrey District Education Centre - feature stair**
(photo credit: Ema Peter)

Atrium (Photo Credit: Ema Peter)

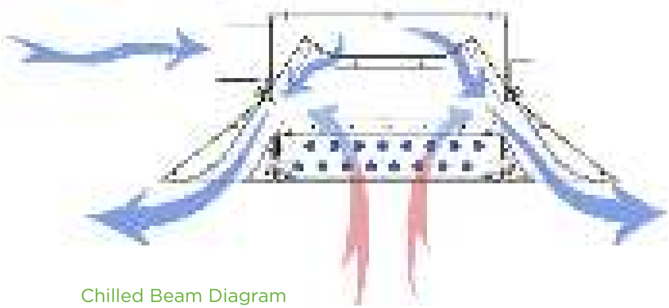
## Energy - Present and Future

The orientation of the building was decided upon based on energy performance that was observed when using energy modelling software. The shape of the building was determined by daylight modelling performed at the Seattle Daylighting lab. The shape and the orientation together increase the amount of natural daylight in the building, while reducing the demand for heating and cooling. The water-based "chilled beam" system has been used in Australia and Asia, but this was North America's largest application and a first in the world at this scale. The projected energy use is 70kWh/$m^2$/year.

The system is almost completely silent in its operations, and occupants report this is the most comfortable building in the school district, with the lowest incidence of "too hot/too cold" complaints.

## Materials and Resources

This project incorporates 38% regional materials and 25% recycled materials. All materials were also screened to ensure that the manufacturing process did not include materials toxic to human health. Finish materials were eliminated where possible to create clean, structural surfaces that will not produce particulates. The building is constructed of concrete containing



Chilled Beam Diagram

Photo Credit: Ema Peter

recycled content to reduce its embodied energy, and heavy timber selected for durability. In addition, 95% of the waste produced during construction was recycled.

## Life Cycle Considerations

There was no cost premium associated with the higher performance of this building. In fact, it came in 12% under budget. Therefore, no life cycle costing was done. This building is expected to last 100 years for the structure and 50 years on the envelope. The design of the building is described as "long-term flexible" allowing this owner to sub-lease their space to multiple tenants, or to change the use entirely to a classroom or a residential building. Narrow floor-plates allow natural lighting through, and exit locations allow maximum flexibility in planning. There are very few interior walls as the space uses an open plan design. Materials were selected to be recyclable when they wear out.

Photo Credit: Ken Wan

# University of Windsor Ed Lumley Centre for Engineering Innovation

**Location** Windsor, ON, Canada
**Size** 310,000 s.f. | 28,800 s.m.
**Client** University of Windsor
**Completion** 2013

**Right:** Main atrium which operates as HVAC buffer zone, with Bio-Filter vertical garden
Photo credit: Toni Hafkenscheid

**The Centre for Engineering Innovation (CEI) is designed to be a living building where students can learn from the electrical, mechanical, civil and environmental engineering systems that are displayed throughout.** It was constructed of recycled materials where possible, and will incorporate a green roof, water recycling, low-energy heating and other sustainable systems.

The University of Windsor wanted to revitalize their engineering program to maintain their reputation as a leader in academic research and scientific study well into the future. They knew that it would take great innovation to accomplish, and for this reason brought B+H on board to design their new flagship facility.

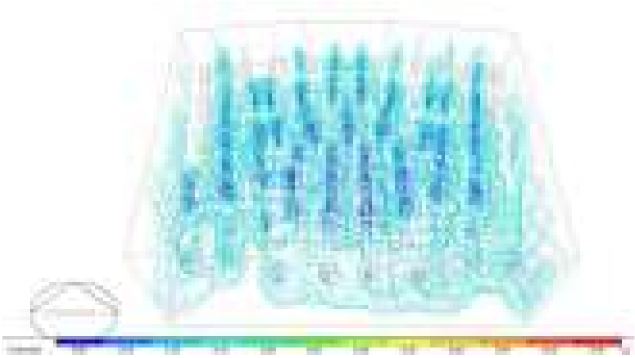
The University of Windsor strives to balance leading edge research with a strong commitment to teaching. The new engineering laboratory has to harness and bolster these mandates within a deep sustainable framework. The culture of sustainability surrounding the facility emphasizes not only the physical architecture and systems, but also the behavioural changes that truly spark sustainable advances – changes that are inspired by an extensive program of building metering and data point monitoring to gain a clear view of true building performance supported by real data.

## A High Performance Facility with Sustainable Technologies

Laboratories are historically very energy intensive. There is a delicate cultural balance being struck between the innovative advances being developed within these types of facilities, and the negative effects of their operation: the significant energy consumed and the often noxious effluents and exhausts that are produced. Nonetheless, there are ways of bettering these energy and pollution negatives. It is very difficult to benchmark, as laboratories are very customized and unique, but a typical energy intensity for a modern laboratory is anywhere between 650 – 850 kWhr/m$^2$/per annum. The University of Windsor CEI Building targets 287 kWhr/m$^2$/per annum.

## Ventilation

Laboratories have very significant ventilation requirements, which is one of the main reasons for their high energy intensity. In designing the CEI, B+H looked carefully at how

**Above:** Displacement Ventilation in Classrooms.
The main teaching spaces are ventilated with advanced dedicated-outside-air ventilation systems. The design team utilized Computational Fluid Dynamics (CFD) software to model the air flows and thermal stratification. Using the CFD software facilitated several iterations of design which resulted in the lowest energy input for the greatest ventilation effectiveness and quietness.

**Right:** Thermal Gradients.

to ensure the ventilation system saved energy while at the same time maintaining excellent indoor air quality. Passive measures are always the greatest source of energy savings. The ideal case is to be able to align the passive energy that is stored up with the availability of renewable energy in such a way that energy can be released at times when it's required by the occupants.

The CEI couples the passive strategy of thermal mass with an active HVAC system. The thermal mass of the hollow-core concrete plank building structure is used as a storage system. A hollow core terminal air delivery system, Termobuild®, activates the thermal storage in order to exploit the free heat given off by the sun, occupants, and equipment.

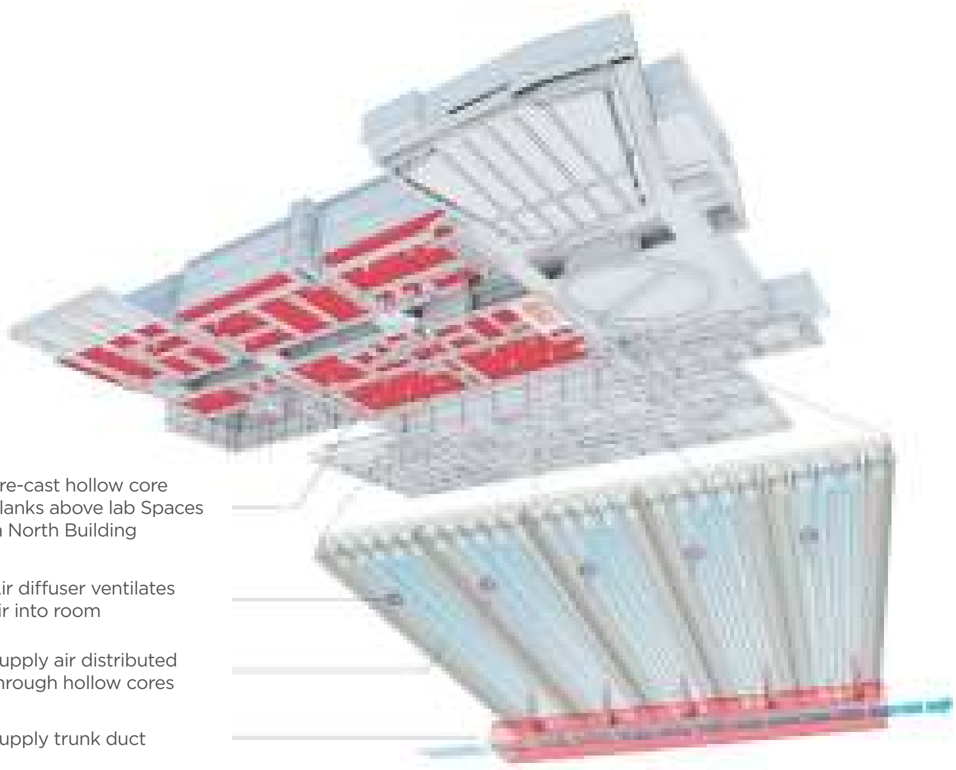
## The Termobuild® Hollow-core Terminal Air Delivery System

The sun heats up the building throughout the day. Occupants and equipment inside the building also generate heat. The heat that these external and internal sources generate is absorbed by the Termobuild® system by means of two transfer mechanisms: by immediate radiation directly from the source into the exposed concrete planks, and through direct conduction as the air passes through the concrete cores and deposits heat

**University of Windsor Centre for Engineering Innovation**
High-performance glazing with glue laminated wood solar shading fins (photo credit: Toni Hafkenscheid).

**Clockwise from top left:** Glue laminated wood structure in graduate student studios; high bay structures lab with 1.5m thick strongwall; wind tunnel lab

**Right:** Precast concrete Hollow-core plank Terminal Air Delivery System. Termobuild® This system integrates the floor structure with the HVAC air distribution system. Air is cycled through the floor planks to deposit and remove heat to the net benefit of the facility i.e. made available as required. The benefits of the systems include recovery of latent heat as absorbed by the concrete flooring planks as well as obviating the necessity of ductwork and ceilings. This results in capital cost savings through reduced fan sizes (fan power reduction of 30%), eliminated ductwork and eliminated ceilings. The battery effect of the concrete to hold substantial amounts of heat result in significant recued energy consumption (air volume reductions).




into the concrete. In the winter, the conditioned air that is delivered through the concrete planks can be cooler than in a conventional all-air system because it heats up on its journey through the concrete to the required interior space. Conversely, during the summer the fans slowly flush out the building overnight, removing absorbed heat so that air can be delivered through the cores warmer than typically, since the pre-cooled concrete will absorb the heat and provide cool air to the occupants. Both modes provide for significant energy savings.

Indoor air quality and ventilation effectiveness are also key factors in providing high performance buildings. Beyond the Termobuild® system, the CEI is also employing displacement ventilation and bio-filter ventilation in key areas.

## Displacement Ventilation

This type of ventilation is provided in the high-capacity lecture theatres, where it not only increases the direct ventilation of fresh air, but also reduces fan pressure to significantly reduce energy consumption. The inherent thermal plumes created by students and teachers carry the fresh ventilated air from low levels to the breathing zone, and displace the stale air upwards towards a stratified zone.

**University of Windsor Centre for Engineering Innovation**
Exterior showing north facade with natural daylighting of interiors (photo credit: Toni Hafkenscheid).

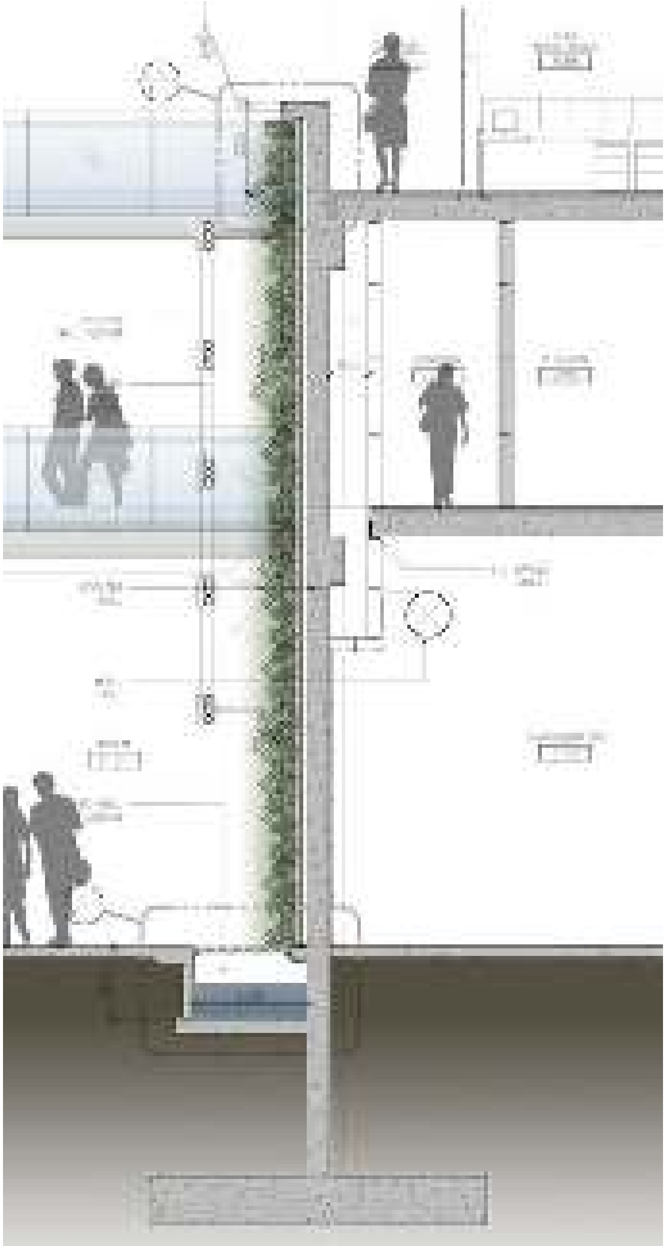
## Bio-filter ventilation

This system strives to increase the cleanliness of the return air by polishing it and removing VOCs, as well as re-oxygenating the air. The system is low velocity and high volume, which results in great ventilation effectiveness with drastically reduced fan pressures, and hence energy savings.

## Measurement and Verification

Buildings require empirical data in order to support ongoing performance improvement. One of the greatest commitments a building owner can make is to allow the building to collect and communicate data about building system performance. The granularity of these data collection systems is paramount to the interpretation of this data flow, such that buildings can be maintained and potentially re-commissioned to continuously improve return on investment.

At the CEI, an extensive network of building system and sub-system metering allows the University to collect a live data stream. From this information the building can be monitored for optimal performance, and can also be used as a learning tool unto itself. The students and researchers can connect in to the network, via a special web interface, to gather the data and study the



**Above:** University of Windsor Centre for Engineering Innovation - Green Wall Atrium (photo credit: Toni Hafkenscheid)

**Right:** Bio-filter ventilation: this system utilizes plantings to filter and refresh indoor air. The vertical garden creates a microclimate that absorbs CO2 and VOCs. As indoor air is slowly drawn across this filter the air is cleaned and oxygenated. The scrubbing and polishing effect on the air stream drastically improves indoor air quality – as well  serving as a lovely indoor landscape amenity.

building. Furthermore, many customized, experimental monitoring scenarios have been programmed into the facility. For example, green planted roof assemblies are monitored for heat flow, water retention, and evapotranspiration. HVAC duct runs are monitored for pressure drops, local building wind patterns are measured, and specialized calorimeters are installed to take precise energy consumption measurements.

**Other sustainable technologies include:**

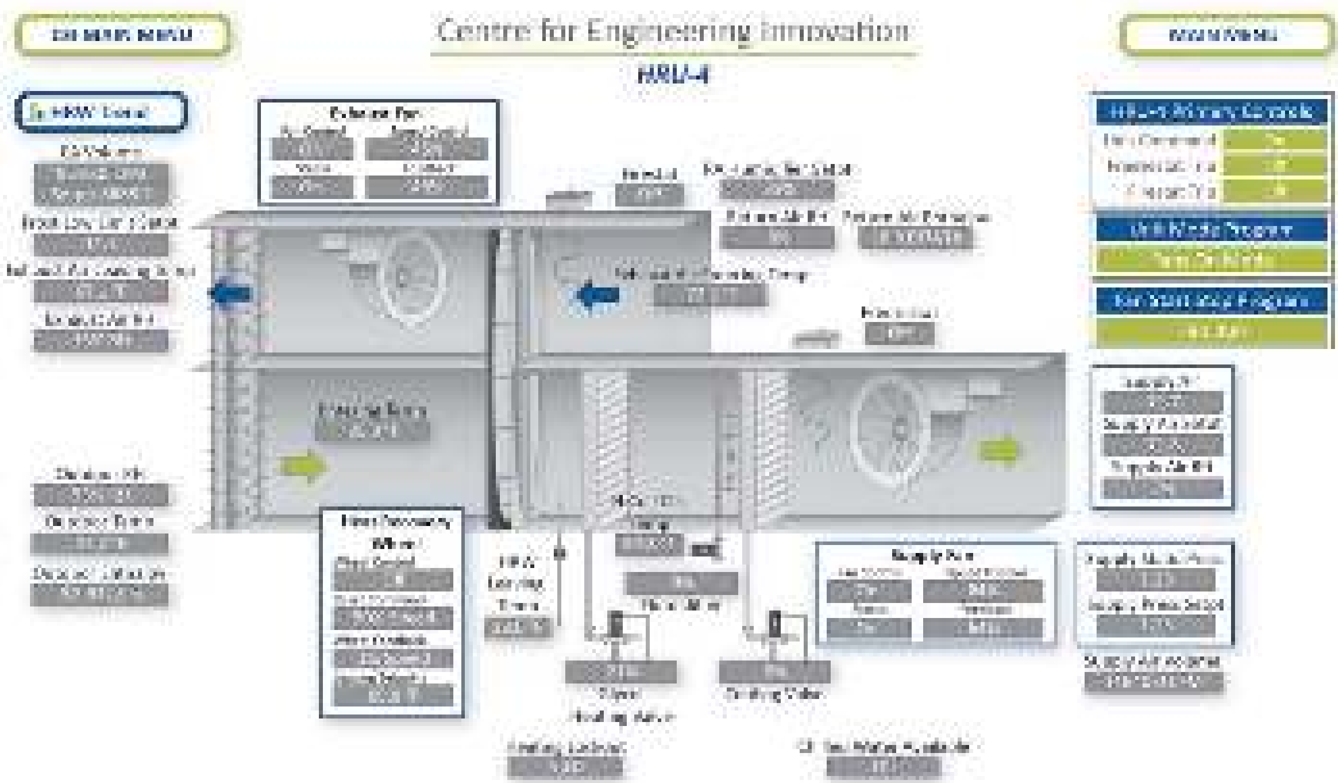
- R30 (effective) envelope
- Ultra-low water consumption
- Storm water recycling for toilets
- Supplementary cementitious materials (SCMs) for concrete
- Instrumented planted roof (for data collection for research into green roof performance)
- High performance – High reflectivity roof membrane
- Fully web-addressable, occupancy/illumination driven lighting system

**University of Windsor Centre for Engineering Innovation**
Opposite page: central atrium with green roof access beyond; this page: central hall (photo credit: Toni Hafkenscheid).

**University of Windsor Centre for Engineering Innovation**
Lecture hall featuring displacement ventilation (photo credit: Toni Hafkenscheid).

The CEI is pursuing LEED® Gold level certification. This certification is one measure of the sustainable commitment the building makes to its students and researchers. The building is a living tool for engineering education, as well as a productive laboratory of technological innovation that will undoubtedly interest and educate the university community and the global sustainable design community.

**Below:** Measurement & Verification as a learning tool: the data collected by hundreds of various building system monitoring sensors will not only drive the Building Automation System (BAS) but will be streamed to a web access portal such that students, faculty and researchers can observe - realtime - the operation of the facility. On top of the necessary BAS data points, the University elected to install an array of supplementary sensors as research based experiments to drive deeper access into the actual working of such a facility. Such supplementary installations included: green roof thermal and water flow monitoring, duct pressure loss sensors, exterior perimeter wind sensors, concrete floor thermal management sensors, VOC & $CO_2$ monitoring for the bio-filter and many more. The graphic study below depicts the data point configuration of an installed Heat Recovery Ventilator (HRU).



**Discovery Green, Burnaby, Canada**
(photo credit: Ema Peter)

# PART 3

## NEXT GENERATION DESIGN

**Getting to net zero energy at the community level** means maximizing the energy efficiency of each building in that community, including many existing buildings, and meeting the remaining energy demand with renewable energy.

Net Zero Communities: One Building at a Time, The Institute for Building Efficiency, August 2012

So far we have discussed the ways in which buildings can reduce their energy use, and the many reasons why going green is so desirable, especially from a business perspective. We've talked about the state of sustainability today, but in order to design the best, most forward-looking buildings, we need to examine some key concepts that are on the horizon.

According to Laszlo and Zhexembayeva in their book *Embedded Sustainability*, there are three major, emerging trends that will continue to impact the global economy in powerful ways:

1. Depleting global resources,
2. Increasing demand for transparency, and
3. Increasing demand for innovation.

The response by sustainable architectural design will be

1. More employment of renewable energy,
2. Increased research through measured and verified performance metrics and design re-commissioning, and
3. Increased creativity developing hyper-efficiency and energy management systems across individual buildings and districts.[30]

First, we must ensure that we're building intelligently, using the most readily accessible methods to improve energy efficiency. This includes designing to maximize passive energy savings, and it also means looking forward to new ways of harnessing **renewable** resources. This also means proving out our designs by measuring and **verifying performance.** Once we are already designing under this paradigm, perhaps the next largest shift in sustainable design **innovation** is the connectivity of buildings within neighbourhoods, districts and cities. Reduction of energy consumption at the scale of individual buildings alone will not be enough. Realizing the benefits of this co-operative approach and designing buildings that take full advantage of new technologies and systems in this area is the only way to globally realize the energy savings we need — to achieve carbon neutrality.

## Renewable Energy

Energy is abundant. In 45 minutes, enough solar energy falls on the earth's surface to power an entire year of our global economy[31]. In addition to solar power, water, wind and modern biofuels are being increasingly used as sources of renewable energy.

In the realm of solar power, heat, cooling and electrical production are all on the increase and can be harnessed

30. Laszlo and Zhexembayeva. *Embedded Sustainability* (Stanford University Press, 2011).
31. Rifkin, Jeremy, *The Third Industrial Revolution* (New York: Palgrave Macmillan, 2011).

**University of British Columbia - Student Union Building, Vancouver, Canada**
Targeting LEED® Platinum. B+H is working in association with Dialog on this project.

by buildings to reduce their need for energy from non-renewable sources.

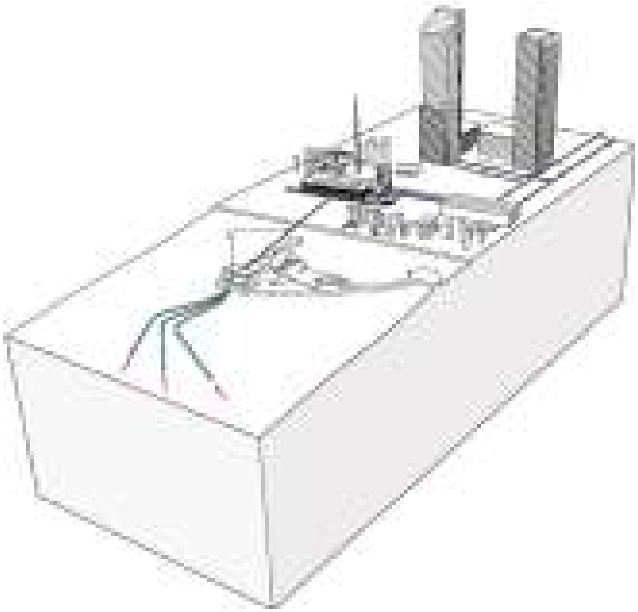
- **Solar heat:** Heat can be collected through a variety of passive and active systems, and used to heat air, water, and interior surfaces.
- **Solar cooling:** Buildings can be cooled through passive design strategies to control how much heat enters and remains in a building, as well as active systems, for example ones that deliver solar energy to chiller devices that produce cold water for use in the building's air conditioning system.
- **Solar electrical:** Sunlight is converted into electricity either using photovoltaic panels, or by passing through a system of lenses and mirrors that concentrates the power.

An examplar project is the UBC SUB (with DIALOG, under construction). We are using solar energy for heating, cooling and power. Solar hot water is used for powering thermal-active structure (radiant slab) and for DHW. It is also used to drive an adsorption chiller for peak load cooling. Roof-mounted photovoltaics also generate electricity for the project.

## Renewable District Energy Cooling Systems

Deep lake water cooling systems are a great example of how clean, renewable energy can be built into the infrastructure of dense urban environments. These systems are used to channel cold energy from large bodies of water to dense urban areas, where the buildings use interconnected cooling systems to share this resource. This provides a much more sustainable system than traditional energy-intensive air conditioning.

The world's largest lake-source cooling system is located in Toronto, and operated by Enwave Energy corporation. B+H is proud to have played a part in the development of this revolutionary system. It was an important component in our design for the RBC Centre, Canada's first LEED® GOLD certified commercial office



**Left:**
**Enwave District Cooling System, Toronto, Canada**
Using the enormous thermal mass of the Lake: the municipal water supply is 'piggy-backed' by the Enwave heat exchanger facility. The deep water stratigraphy exhibits a consistent thermal profile; and so becomes a very efficient heat sink for the super-high occupancy commercial business core HVAC systems. Approximately 50,000 tonnes total cooling capacity is achieved by circulating the deep lake water.

building greater than 1000,000 square metres or 1 million square feet.

The Enwave system uses three intake pipes to draw cold water from Lake Ontario five kilometres off the shore at a depth of 83 metres below the surface. The cold water continues through the John Street Pumping Station for normal distribution into the City water supply. Enwave uses only the coldness from the lake water, and at a depth where the temperature is affected by 1 degree celcius, not the actual water, to provide the alternative to conventional air-conditioning.

## Empirical Transparency

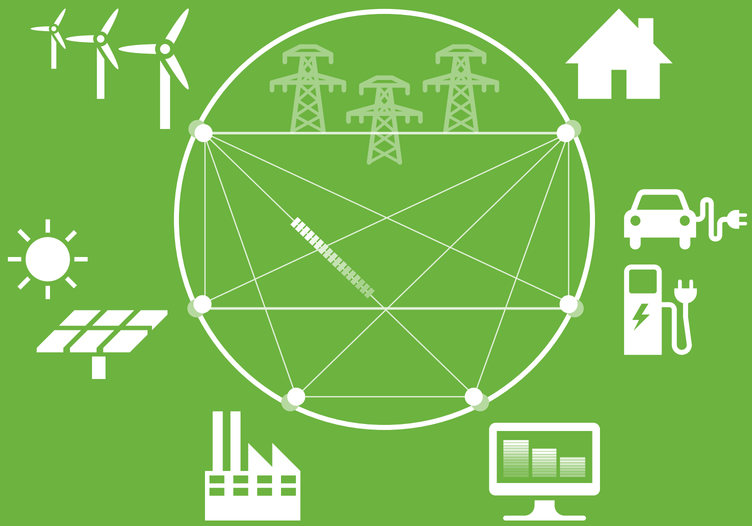
Empirical performance measures are the greatest tool we have to move building design towards ultra-high performance. Only after having an intimate understanding of how buildings actually perform in situ, under all the demands of the programme and users, will designers possess the necessary feedback to fine tune future designs. Measurement and verification protocols provide this feedback, and understanding how to best collect and manage building performance data leads to better, more transparent evaluation.

A precedent project is the Queen's University Integrated Learning Centre, where we are using a LIVE building strategy to collect, and most importantly, re-present building performance data in a graphical, web-based interface. Students, researchers and the public use the internet to see real-time data from the building automation systems data points, as well as other dedicated and experimental data point installations such as thermal sensors across building wall assemblies, bio-filter wall VOC scrubbing, lighting level intensities, etc. Ultimately the building, unto itself, serves a learning tool to foster future research and development – driving towards higher performance.

## Scale Jumping

Scale jumping means a perspective shift from the immediate building and its occupants to looking at energy consumption on a larger, multiple building, scale. Buildings are designed to serve different purposes and therefore have unique energy demands and energy usage patterns. For example, a typical commercial building uses the most energy during business hours,

**Smart Grids:**
The emergent smart grid combines information technology with electricity service. The conventional models follows large, inefficient central power plants (often carbon fuel fired) providing electricity to very large geographic regions. The flow of electricity is one-way from utility provider to consumer; and there is very little associated communication. Redundancy is limited and provision of power must exactly match the demand – otherwise a black-out results. The smart grid enables the distribution of power production towards smaller, more local and more diversified sources – often renewable sources. With an array of multiple sources the smart grid can choose the source to match the demand in a realtime mode because the consumer and utility communicates across the grid with information about their respective power production & consumption profile. This also means that the consumer can become a producer when they have generated excess power. The coupling of electricity distribution and intelligent communications allows for a two-way flow of both power and information.



and a typical residential building consumes the most energy during the evening. If these patterns can be overlaid, then the opportunities to share energy become apparent and the feasibility of distributing energy in a synergistic way can be assessed. This idea of an orchestrated sharing of energy is not only relevant to highly industrialized countries. In developing countries, the "Third Industrial Revolution"[32] is seeing people moving towards having their own power, moving it around between their homes, offices, and factories in an "energy internet", and as a result developing a power-based economy.

## Smart Grids

There is no longer simply a one-way flow of power from the source to the consumer. We are now seeing the development of multi- directional communication networks where power is bought, sold and managed with data interchange.

Some power is now created by the consumer and sold back into the grid. Both power and data must flow to ensure that a fully integrated network is maintained. Energy usage profiles can be created and analyzed and ultimately optimized by the smart grid.

In Europe, smart grid systems have been growing in number and in scope. To give just one example, the city of Mannheim in Germany is currently engaged in a project called Model City Mannheim, which aims to develop an "energy marketplace of the future".

The approach it's implementing features a real-time communications network to support all the players in the energy marketplace (consumers, producers, traders

32. Rifkin, Jeremy, *The Third Industrial Revolution* (New York: Palgrave Macmillan, 2011).

# Global investment in renewable energy projects is estimated to reach **$7 trillion by 2030**, and as a result, 15.7% of total energy production is predicted to come from renewable sources by that time

Bloomberg New Energy Finace, "Global Renewable Energy Market Outlook", 2011.

and others), and a variable pricing structure that is dependent on changes in supply and demand.[33]

Beyond individual cities, Europe is mapping out an even broader vision, in which grid systems will become more inter-operable at a European level to enhance security and cost-effectiveness[34].

## Culture of Performance

Ultimately, the future of serious high performance design lies in applying all these trends in combination with the total involvement of the designer, operator and occupant into a culture of performance and sustainability. The more intensely the design can foster this kind of unique, building-by-building centered sustainable culture, the greater the performance enhancement. Good sustainable design has the power to self-promote and positively reinforce its mandate towards higher performance, greater functionality and improved amenity. Buildings working individually and in tandem, to bolster enduring concepts and methods of sustainability will afford both a pragmatic and inspiring path to the future.

**RBC Centre, Toronto, Canada**
Registered and targeting LEED® Gold

33. MVV Energie, www.mvv-energie.de
34. "Strategic Research Agenda for Europe's Electricity Networks of the Future", European Commission Community Research, 2007

**Discovery Place -**
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**Vancouver, Canada**
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