BUILDING SCIENCE ROUNDTABLE FALL 2015

Defining, Measuring and Predicting Building Performance

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BUILDING SCIENCE ROUNDTABLE — CLOSING THE GAP

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The Toronto skyline of a decade ago is unrecognizable today, and will be further transformed by intensification in the decades ahead. Ontario cannot achieve sustainable growth in buildings that do not attain measurable levels of social, environmental and economic performance. [Photo: Ted Kesik.]

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Building Science Roundtable Fall 2015: Defining, Measuring and Predicting Building Performance

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The Building Science Roundtable acknowledges the collegial assistance of Alex Lukachko and Melissa Pound of RDH Building Science Inc. for organizing and facilitating this roundtable forum.

Executive Summary

The inaugural Building Science Roundtable in April 2015 revealed there is a genuine concern about the quality of building design, construction and operations, as well as the capacity of the building industry to develop and engage sufficient qualified personnel to deliver durable, efficient, comfortable and resilient buildings. The second roundtable conducted in October 2015 concluded that if Ontario's growth is to be sustainable and its economy globally competitive, our building industry needs to deliver reliable building performance more consistently and cost effectively.

Now is the time to start closing the gap between promise and performance.

Canadians would be well served to express higher expectations for the performance of their buildings because we now more fully understand how the quality of our buildings impacts human health, well being, our environment and the economy. Next to our personal lifestyle habits, the quality of the built environment is the most significant determinant of our health and well being.

Buildings with performance problems demand expenditures that could be avoided through better design, construction, commissioning, operation and maintenance. Avoided costs could be diverted toward investments in innovation and the provision of enhanced services in areas such as health care, education and the environment. We cannot afford to blindly continue constructing unsustainable buildings that will burden future generations with excessive operating, maintenance and repair costs, while contributing to irresponsible levels of greenhouse gas emissions and water consumption.

A key conclusion by the roundtable is that the absence of information sharing by stakeholders is among the biggest problems affecting the responsible stewardship of Ontario's building assets. Withholding building performance information for fear of prejudicing leasing opportunities leaves all building owners/manager in isolation when many challenges can be avoided through timely transfer of information. If you can't measure building performance, you can't manage it - this truism has been ignored by the buildings sector to the detriment of building owners and occupants.

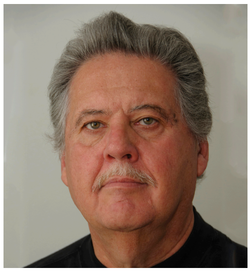
Good housekeeping through better building information is mission critical. There is no formal system or framework in place for compiling, sharing and accessing building information. Numerous organizations and agencies across federal, provincial and municipal jurisdictions collect information about buildings and these have yet to be harmonized into a cohesive knowledge-based resource made accessible to the building industry, government, academic researchers and consumers. Feedback loops based on the reporting of measured performance, not predictive computer modeling, must be incorporated into all sectors to improve how buildings are designed, operated and maintained.

The Building Science Roundtable recommends that stakeholders work together to address opportunities and challenges through a coordinated action plan:

- *Development of an online Buildings Ontario knowledge base;*
- *Mandatory continuing education for design professionals about building performance;*
- *Innovative professional practice models to deliver acceptable building performance;*
- *New requirements in building codes for design review, quality assurance and whole building system commissioning;*
- *Training and education programs for measuring, maintaining and enhancing in-service building performance; and*
- *Government/Industry funding partnerships for building performance R&D aimed at achieving better performance outcomes.*

We must be able to better define, measure and predict what really matters in the performance of our buildings, new and existing, if we hope to build a sustainable future across Ontario.

Building Science Roundtable Panelists



Ted Kesik, Ph.D., P.Eng., is a professor of building science in the John H. Daniels Faculty of Architecture, Landscape and Design at the University of Toronto. He entered the construction industry in 1974 and has since gained extensive experience in the various aspects of building enclosure design, systems integration, quality assurance, commissioning, and performance verification. Professor Kesik's research interests include high performance buildings, durability, life cycle assessment, systems integration and sustainability. Dr. Kesik continues to practice as a consulting engineer to leading architectural offices, forward thinking enterprises and progressive government agencies.

John Straube, Ph.D., P.Eng., is a Principal at RDH Building Science Inc., where he heads forensic investigations and leads research projects in the areas of low-energy building design, building enclosure performance, hygrothermal analysis, and field monitoring of wall assemblies. A prolific writer and a noted public speaker, Dr. Straube is also a cross-appointed faculty member in the School of Architecture and the Department of Civil and Environmental Engineering at the University of Waterloo. Dr. Straube has traveled across North America, South America, Europe, Asia and the Caribbean, working on projects that have ranged from investigating failed office towers to consulting on historically sensitive retrofits.

Dr. Mark Gorgolewski is a Professor in the Department of Architectural Science at Ryerson University in Toronto. He has worked for many years as an architect, researcher and sustainable building consultant in Canada and the UK. He has been a director of the Canada Green Building Council and chair of the Association for Environment Conscious Building and is a LEED Accredited Professional. Dr. Gorgolewski has worked for many years as an architect, researcher and sustainable building consultant in Canada and the UK. He has been a director of the Canada Green Building Council and has written many papers and books on the subject of sustainable built environments.

Stephen Pope is an architect and promoter of strategies for an effective and sustainable built environment. A former NRCan CanmetENERGY researcher, Stephen has considerable experience with modeling operations energy, and the embodied effects of buildings. He supports effective design through energy research, design facilitation, and has delivered over 125 presentations on energy efficiency for commercial buildings since 2001. He is a Fellow of the Royal Architectural Institute of Canada and Chair of the Board of Directors of the ATHENA Sustainable Materials Institute.

Scott Armstrong, Dipl. Arch. Tech., CET, LEED AP is an Associate at WSP Canada Inc. and manager of Building Science consulting services. His expertise includes building envelope consulting and retrofits, roof consulting, sustainable cladding analysis, LEED consulting, integrated design facilitation, and green roof consulting for clients with new and existing buildings. His previous projects have spanned commercial, institutional, heritage, recreational, residential, and neighbourhood development sectors in Canada, the US, the Caribbean, and the Middle East. As a LEED® Accredited Professional and past Board member of the Canada Green Building Council Greater Toronto Chapter, Scott is a regular speaker on the topics of both building envelope design and green building strategies.

Defining, Measuring and Predicting Building Performance

Overview

This Building Science Roundtable is organized by the University of Waterloo, Ryerson University, George Brown and the University of Toronto. Roundtables bring together academics and industry experts to explore issues through open dialogue that is then shared with the larger building science community and stakeholders. Roundtable partners recognize the issues are complex and do not have simple solutions. They will require the cooperation of many stakeholders to resolve. The roundtables seek to identify and examine the big issues related to buildings across the Greater Toronto and Hamilton Area (GTHA) where the majority of Ontario's growth and development will take place over the next 25 years.

The inaugural Building Science Roundtable in April 2015 revealed there is a genuine concern about the quality of building design, construction and operations, as well as the capacity of the building industry to develop and engage sufficient qualified personnel to deliver durable, efficient, comfortable and resilient buildings.

Feedback from roundtable participants indicated a priority issue was defining, measuring and predicting building performance. This report on the October 2015 roundtable explores metrics to improve and advance the performance of both new and retrofit buildings, and asks how we go beyond current industry priorities of "To Code, On Time, On Budget" to include other important issues.

Context

According to 2013 - 2041 population projections for Ontario, The Greater Toronto Area (GTA) is predicted to be the fastest growing region of the province, with its population increasing by almost 3.0 million, or 45.8 per cent, to reach over 9.4 million by 2041. The GTA's share of provincial population is projected to rise from 47.6 per cent in 2013 to 52.9 per cent in 2041.[1] Statistics Canada reports that about two-thirds of the $30.7-billion expended in 2014 on building construction across Ontario was invested in the GTHA and this figure does not include the retrofit of existing buildings. By 2041, some $500-billion of new building construction will be completed across this region, accompanied by hundreds of billions of dollars of investments in the renewal of existing buildings. Looking at all of southern Ontario, an estimated $1-trillion will be expended on new and existing buildings over the next 25 years.

Although many buildings in the U.S., Canada, U.K., and elsewhere claim to be "green," "low energy," or "high performance," it is rarely clear on what evidence or data these claims are based. Such claims cannot be credible without standardized performance measurement protocols that are applied consistently. If claims of superior building performance are to be believed, it is essential that a common set of measurements be used and the results reported against meaningful benchmarks. Such protocols are also needed to give usable feedback to building designers and operators when measured performance does not match design intent. [2]

In 2010 the American Society of Heating, Air-Conditioning and Refrigerating Engineers (ASHRAE) published *Performance Measurement Protocols for Commercial Buildings*. Protocols are now available at three levels of resolution in each of six performance categories: energy, water, thermal comfort, indoor air quality (IAQ), lighting, and acoustics. These represent the kinds of best practices needed to provide reliable building performance information to stakeholders.

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[1] *Ontario Population Projections Based on the 2011 Census*. Ontario Ministry of Finance, Fall 2014. http://www.fin.gov.on.ca/en/economy/demographics/projections/projections2013-2041.pdf

[2] Hunn, B.D., Jeff S. Haberl, Hywel Davies and Brendan Owens. 2012. *Measuring Commercial Building Performance*. ASHRAE Journal, Vol. 54, No. 7, July 2012.

If Ontario's growth is to be sustainable and its economy globally competitive, our building industry needs to deliver reliable building performance more consistently and cost effectively.

Buildings must become more resilient in the face of climate change that is driving an increasing frequency and severity of extreme weather events such as tornados, ice storms and flooding. The durability of buildings has to be enhanced to protect against premature deterioration, and their designs must be more flexible and adaptable to affordably accommodate shifting demographics and changing uses over the building life cycle. Economic growth will challenge Ontario's ability to achieve greenhouse gas emission reduction targets, unless buildings become far more energy efficient, and communities are designed around pedestrians and public transit rather than the automobile.

Ontario has an opportunity to become a global building industry leader, advancing innovation in architectural and engineering design, procurement, construction, commissioning, facilities management, materials, product technologies, technical services and sustainable development.

Now is the time to start closing the gap between promise and performance.

What is Building Performance?

Building performance has many dimensions ranging from the aesthetic and social, to the environmental and economic aspects of buildings. The physical aspects of building performance become evident when problems arise, such as water leakage, discomfort, unacceptable indoor air quality, high energy costs or premature deterioration.

Building science defines "*building performance*" as *"the level of service provided by a building material, component, assembly or system, in relation to a required, intended, or expected, threshold or quality."* For example, the performance of the structural system in a building may be assessed in terms of its resistance to loads (i.e., dead, live, soil, wind and earthquake). Within the thresholds established by applicable codes and standards, the structural system is expected to perform adequately in terms of durability, strength, deflections and vibrations. Performance requirements and expectations also apply to components such as windows, and materials such as roofing membranes, sealants and paints.

Building performance problems are seldom catastrophic but they are often costly, disturbing and disruptive to owners and occupants. Basement flooding is a good example of a building's failure to manage the intrusion of water that may not put building inhabitants in danger, but often causes costly damage and inconvenience. Leaking roofs and walls are among the most common problems in buildings, where extensive and chronic leakage over large parts of the wall/roof area signifies a *failure*, while a minor leak, in an otherwise well performing assembly, indicates a *defect*. Buildings should not *fail* to perform critical functions, but it is normal and acceptable there may be the odd *defect* that needs to be corrected and/or adjustments made.

Concepts of performance, failure and defect can also be extended beyond the technical realm to the more architectural and cultural aspects of buildings, however, it should be recognized that the criteria and methods of measurement are often far less objective and quantifiable. The presence of a requirement for beauty in the Living Building Challenge performance assessment system became the springboard for the October 2015 Building Science Roundtable to explore the cultural aspects of building performance in greater detail. This discussion shone a light on the great diversity of cultural definitions of beauty, which vary with the diversity of stakeholder groups engaged in the procurement, design, construction, operations, and occupancy of buildings. Each different stakeholder group has a concept of beauty that while not measurable in the same sense as the physical characteristics of building science, is no less defined. Connecting the various cultural definitions to building science practice will be a substantial challenge for the promotion of building science objectives in the coming times.

Canadians would be well served to express higher expectations for the performance of their buildings because we now more fully understand how the quality of our buildings impacts human health, well being, our environment and the economy.

Legacy or liability? Concerns raised by building scientists about the long-term performance of the exterior glass walls in hundreds of recently constructed condo towers across the Greater Toronto Area have still not been addressed in building codes and through better warranty protection for consumers. [Photo: NeoGAF.]

Why Is Building Performance Important?

In a cold-climate country like Canada, buildings are essential to provide shelter from the elements. Canadians have more money invested in buildings than in any other sector of the economy. From a domestic perspective, the top three household expenditures by Ontario households are shelter, transportation and food. For the average household, the cost of housing, including its operations, is roughly equal to the cost of transportation and food together.

From a business and institutional perspective, building facilities represent a significant overhead after expenditures on the wages and benefits of employees. Poorly performing buildings put a dual stress on businesses, institutions and the government sector, because rising overheads associated with their inefficient and deteriorating facilities are compounded by demands for wage increases by workers to cover their own rising costs of shelter.

Buildings that are durable and efficient are economical to occupy, operate and maintain for households, and reduce overheads related to building facilities serving the commercial, industrial and institutional sectors.

Buildings with performance problems demand expenditures that could be avoided through better design, construction, commissioning, operation and maintenance. Avoided costs could be diverted toward investments in innovation and the provision of enhanced services in areas such as health care, education and the environment.

Build cheap, maintain expensive. Building science research and numerous studies reinforce the fact that marginally higher costs for improving the performance of buildings at the time of construction are cost effective investments, not just in the short term, but over the life cycle of the building. Rehabilitation of deteriorating buildings is disruptive and many times more expensive than better quality design, materials and constructions practices. [Photo: Ted Kesik.]

Ontario will have difficulty competing in the global economy if it fails to manage the escalating costs of its buildings infrastructure, which like the buried municipal infrastructure and our system of roads, bridges and transit, will continue to crumble without significant investments in their renewal. But it makes no sense to fix existing infrastructure if we do not learn from our past mistakes.

Continuing to construct unsustainable buildings will burden future generations with excessive operating, maintenance and repair costs, while contributing to irresponsible levels of greenhouse gas emissions and water use.

The carbon footprint and water efficiency of buildings are aspects of environment performance that rival economic imperatives. Buildings in Canada account for about a fifth of our total greenhouse gas emissions. Transportation, in particular cars, accounts for the largest source of greenhouse gas emissions. But unlike buildings that typically last more than 100 years, the average service life of a car is about 10 years. Advances and innovations in automotive technology can drastically reduce our greenhouse gas emissions over a relatively short period of time compared to buildings. It is also much easier, less costly and disruptive to reduce our transportation sector's carbon footprint than to retrofit our existing buildings. Retrofitting buildings for energy efficiency is many times more costly than the incremental cost of making them durable, highly energy and water efficient in the first place.

In Ontario, roughly half of our commercial and institutional buildings are 50 years or older. Examples of commercial or institutional buildings include elementary and secondary schools, colleges and universities, hospitals, inpatient health care centres, office/professional buildings, warehouses, grocers, enclosed shopping malls, other retail centres, religious-worship buildings, food services and restaurants, hotels and motels, and public assembly buildings. Of these aging buildings, nearly half are 75 years or older. Similar statistics apply to the residential buildings containing the 4,887,510 households across Ontario reported in the 2011 Census. Information regarding the deferred maintenance for Ontario's building stock is not collected, but if public sector reporting by housing authorities, school boards and other public sector facilities such as municipalities, universities, colleges and hospitals are any indicator, wide scale renewal, rehabilitation and retrofit of buildings is needed now. This is an opportunity to go beyond cosmetic renovations and promote deep retrofits that cost effectively enhance the performance of old buildings.

Building performance is important because we cannot live without buildings and yet poor performance contributes to unsustainable operating and maintenance costs, greenhouse gas emissions and water consumption, while diminishing our quality of life.

Next to our personal lifestyle habits, the quality of the built environment is the most significant determinant of our health and well being.

The ripple effects of poorly performing buildings impact every sector and impair our economic competitiveness, housing affordability and the health of the natural and built environments.

Building Performance Stakeholders and Attributes

Building performance information serves the diverse interests of a large number of stakeholders even though they may not be fully aware they need vital statistics about buildings. The key stakeholders comprise architects, engineers, spec writers, constructors, manufacturers/suppliers, utilities, consumers (buyers/tenants), facilities managers, developers, investors, insurers, warrantors, government agencies, and society at large. The environment is also a stakeholder that is only recently finding a voice at the table of sustainable development.

Just as there are diverse stakeholders, there are many kinds of metrics that make up performance attributes. Statistics about the number of housing starts, the value of building permits issued in each province, and housing and dwelling characteristics are collected by Statistics Canada and made available online. Private sector for-profit organizations collect specialized information about various building markets, such as the size and price of new condominiums. But much of the information needed to help stakeholders to conduct scientific research, formulate effective policies and make better decisions is woefully lacking. What follow are some examples of critical information that various stakeholders are missing today.

Architects, engineers and specification writers do not have access to reliable data about the durability and service life of various building components and assemblies, such as windows, walls and roofs. Unlike the automotive industry that collects information about product life and warranty claims, it is difficult for design professionals to predict maintenance requirements and the service life of materials, components, assemblies, equipment and buildings. In the absence of statistically significant data, reserve fund studies prepared for condominium owners are simply guessing at future replacement costs and have no way of realistically anticipating special assessments.

Energy utilities that wish to incentivize energy efficiency cannot effectively target programs in the absence of building characteristics data that correlate the type, age and use of buildings with conservation opportunities for measures such as envelope retrofits, HVAC and lighting upgrades, water conservation and smart controls.

Without energy and water efficiency labeling, and ratings for durability, thermal comfort and carbon footprint for buildings, it is not possible for consumers to make meaningful comparisons between the performance of available choices.

Investors in buildings, such as many of Ontario's pension funds, have to expend considerable time, effort and resources to exercise due diligence and conduct conditional assessments of facilities before purchasing them for their portfolios. In the absence of performance benchmarks it is difficult to compare the condition and quality of a prospective building asset with other similar types of building assets.

In order to properly and fairly manage risk, insurers and warrantors, such as Tarion, require critical data about the predicted performance of buildings based on their design and the track record of the design professionals and constructors executing the project. Claims records of building design professionals must become accessible by prospective clients seeking competent services.

Municipal government agencies are responsible for enforcing the Ontario Building Code including requirements for water and energy efficiency. There is presently no feedback loop that compares the level of performance required by the codes and standards with what is actually being achieved.

Provincial government agencies such as Infrastructure Ontario cannot set appropriate performance standards for P3 projects in the absence of actual building performance data. Currently there is no scientific or statistical basis for the predicted service life promises underpinning P3 projects.

Federal government agencies such as Statistics Canada and CMHC need stronger mandates to update the types and quality of building information needed to intelligently guide social, economic, technological and environmental policies that influence the sustainability of our built environment, in particular our big cities.

The sharing of information by stakeholders is among the biggest problems affecting the responsible stewardship of Ontario's building assets.

Bits and pieces of data can only be found piecemeal among the various silos. Existing legislation often prevents researchers from accessing data needed to assess performance, such as energy and water consumption, or even building floor area. This lack of information about building characteristics and performance profiles is also the root cause of so little research, development and innovation taking place across Ontario's building industry, simply because there is no way of assessing the market potential of new products and services.

Information about building performance in Canada is incomplete and difficult to access. This is an unfortunate reality that impacts a large number of stakeholders. In Ontario, we do not have a comprehensive inventory of our existing building stock (the data reside across a number of disconnected agencies), and we have failed to develop and collect a standardized set of building performance attributes that would provide insights into our building demographics. If the quality of information about the health of

Ontarians was as limited as the building performance information we possess today, our health care system would have no idea about life expectancies, the prevalence of disease, causes of death and expenditures on treatment.

If you can't measure building performance, you can't manage it - this truism has been ignored by the buildings sector to the detriment of building owners and occupants.

Measuring Building Performance

The measurement of building performance is not a straightforward process like measuring distance. First, there are a large number of performance attributes and these hold different relevance among stakeholders. Environmentalists want buildings to be energy and water efficient, while facilities managers are interested in their ease of operation and maintenance. Second, some measures are localized and discrete while others are generalized and holistic. For example, a sample of an air barrier membrane may be tested to determine if it meets applicable performance standards, while a whole building airtightness test is needed to determine the overall performance of the air barrier system. While the overall airtightness may be acceptable, additional inspection during airtightness testing must be conducted to identify defects (discontinuities or leaks). Third, building performance involves incommensurable attributes that cannot be reduced to a single assessment rating. It is possible to have a building that is very energy efficient but with unacceptable levels of daylighting or poor indoor air quality.

In practical terms, it is far easier measuring performance than synthesizing a large number of performance metrics into an overall assessment of building performance. For building scientists, measuring building performance is in many ways more straightforward than for other stakeholders simply because a large number of standardized test methods are available to assess the performance of materials, components, assemblies and systems prior to, during, and after construction. Protocols for condition assessments, energy audits and post-occupancy evaluations are well established. Typically the biggest barrier is whether someone is willing to pay the cost of measuring building performance.

Other barriers include the undesirable impact of market differentiation created by reports on building quality. Designers and constructors may not want to have the quality of their work assessed and provided to the owner, whereas investors in building assets, such as real estate income trusts or pension funds, may insist on assessing the condition and performance of a building asset to inform investment decisions.

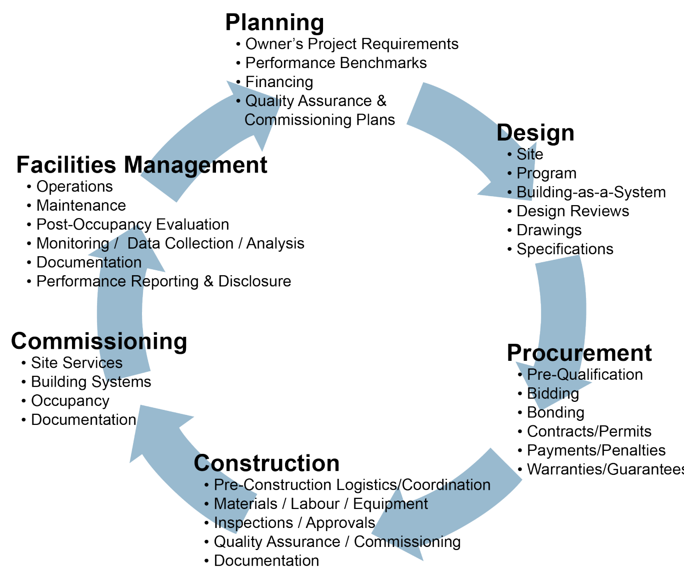
Good housekeeping is exemplified by better building information. There is no formal system or framework in place for compiling, sharing and accessing building information. Numerous organizations and agencies across federal, provincial and municipal jurisdictions collect information about buildings and these have yet to be harmonized into a cohesive knowledge-based resource made accessible to the building industry, government, academic researchers and consumers.

A notable challenge in the reporting of building performance involves complexity of measurement and/or prediction versus complexity of performance concepts. This can be illustrated by means of comparative examples. Durability is difficult to assess in existing buildings and even more challenging to predict at the design stage, but the metric of time used to describe durability is quite intuitive. Most people looking at a 20-year roofing system will take it to mean there will be no need to replace the roof for about 20 years. They would need to possess more sophisticated knowledge about roofs to appreciate that periodic inspection and maintenance are required to achieve this predicted service life. By contrast, thermal comfort can be quite reliably predicted at a point within a space given the characteristics of the enclosure, the occupant, outdoor climate conditions, HVAC system, etc. But it is an extremely difficult performance attribute to convey to non-experts, even though the sensation of discomfort is immediately recognizable when directly experienced. It can be seen from these examples that building performance poses challenges to building science experts and building end-users alike. Like fish in water, we give little thought to the performance of the built environments we inhabit and to be able to discriminate between various types of building performance requires some degree of education, especially for consumers.

During the discussion of measurement versus prediction, the roundtable participants debated the use of hierarchies of data in addition to the presence of different definitions for a common measure held by different stakeholder groups. There was an agreement that properly developed physical measurements remained the gold standard for performance, and all else followed lower down in the hierarchy. Predictive approaches, when calibrated to actual measurements were agreed to be extremely useful, however a significant amount of time was spent on the discussion of confusion in the use of energy simulation tools.

The growth of plug-ins for building information modelling (BIM) tools that propose to automatically produce energy consumption results for a building in the design phase suffer from lack of documentation regarding default assumptions and calculation methods. Similarly, the confusion of code compliance design-level simulations with calibrated energy models has resulted in performance gaps between predictions made for assessment systems such as LEED, and actual utility bills. While design level energy models are useful tools for internal comparisons in the absence of better information, the use of standardized weather files, occupancy, and equipment schedules cannot be expected to produce results closely matching real measurements.

Among the big issues related to building information is the right to privacy versus our right to know and the common good. Looking at the precedents set within Canada's census process, it is possible to gather data from individuals and organizations that can be statistically aggregated and analyzed without revealing data from a particular source. It is not so important to know the energy and water consumption of a particular high-rise apartment building as it is to know the critical benchmarking statistics for the entire population of high-rise apartment buildings according to characteristics such as age, type of construction, size, location (city), etc. When organizations like Statistics Canada started collecting building information over half a century ago, the performance of our building stock was not on anyone's radar. Today, we realize it is important to identify building information needs for a broad cross-section of stakeholders and the time has come to bring together government, industry, academia and consumers to develop a comprehensive building information framework.



Information flows and feedback loops deliver better buildings. Best practices for all aspects of the building process have been developed and are readily available for implementation. Building performance problems arise when best practices are ignored or cut out of project budgets. Cheap buildings make for a false economy reflecting unsustainable growth.

Building performance data form part of a larger building information network and currently it is very difficult to extract all kinds of data needed to deliver better building performance. Disclosure and reporting of energy and water use are not enough because related bits of data are embedded in other repositories that are disconnected from one another.

If government wishes to harmonize policies for reducing our carbon footprint in the residential buildings sector with the demand-side management programs of energy utilities, data about building characteristics, peak and annual energy/water demands and household demographics are needed to develop and target effective strategies.

There are countless examples of where building information, including performance data, is simply not collected, and if it is, it is not required to be systematically reported to a central authority.

Performance improvement demands performance information, preferably at the planning and design stages of a building project, new or retrofit. Mounting evidence suggests that voluntary labeling programs, such as LEED, have not reliably and consistently delivered improvements to building performance. One of the most recent and significant findings from a survey of LEED and non-LEED certified buildings, is that there is no statistically significant difference in occupant satisfaction levels with indoor environmental quality.

> *Therefore, it can be concluded that there is not a significant influence of LEED certification on occupant satisfaction with indoor environmental quality, although the analysis of mean votes of satisfaction reveals that occupants of LEED buildings tend to be slightly more satisfied with air quality, and slightly more dissatisfied with amount of light.*[3]

Feedback loops based on the reporting of measured performance, not predictive computer modeling, must be incorporated into all sectors to improve how buildings are designed, operated and maintained.

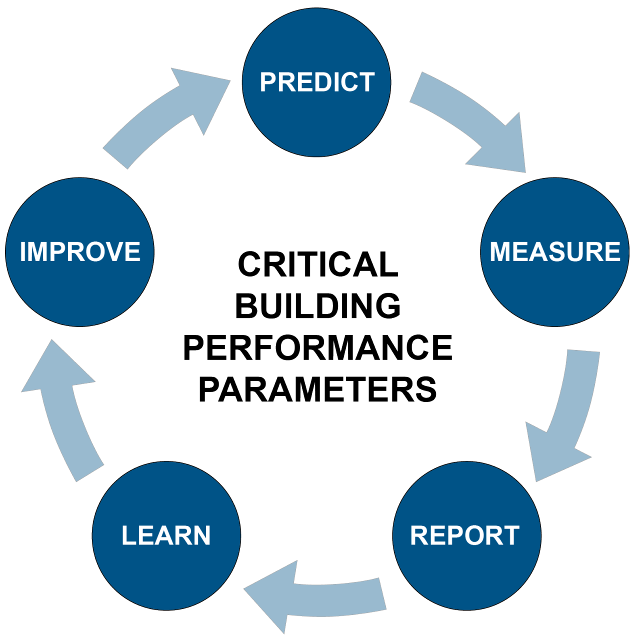
Additional research into other significant indicators of building performance is needed. At the design stage, the calculation of the overall effective R-value of the building envelope is straightforward and emerging evidence suggests it is a good indicator of energy performance for space heating and cooling. Such a requirement could easily be integrated into future code revisions. As part of building envelope commissioning, whole building airtightness testing is a means of ensuring the effective performance of the air barrier system. But it may also serve as an indicator of envelope construction quality since achieving airtightness demands attention to detail in workmanship. Some jurisdictions in the U.S. and Europe now require such testing in their building codes. Clearly, research, development and demonstration of simple and cost effective methods for measuring performance is a critical priority for advancing the design and construction of buildings. While there are numerous means of measuring performance to determine if and why buildings have failed to perform, it would be preferable for the building industry to become more proactive and predictive.

Predicting Building Performance

Buildings are highly complex products, designed by teams of professionals, integrating myriad materials, components and systems, which are assembled by diverse trades employing a variety of tools and equipment, and then operated and maintained by often untrained individuals responding to an ever changing population of occupants. It is truly amazing that buildings so seldom completely fail to perform, yet there is a wide range of quality and performance evidenced across our building stock. It would be even more amazing to be able to close the performance gap and better predict actual performance at the design stage for a product where so many variables contribute to its performance outcome. Other industries have managed to bring high quality and consistent performance to their products through an integrated system of engineering and quality assurance focused on measurable outcomes. Success in complex endeavors involving many players is often determined by the quality of feedback loops and learning not to repeat past mistakes.

Building science has the potential to make better buildings without compromising architectural delight, any more than concerns for safety or fuel efficiency have compromised the beauty of automobiles and airplanes. Today there is often an unacceptable performance gap between the construed versus the constructed building. Unfortunately in most cases, this becomes apparent only after the facility is completed and occupied.

[3] Altomonte, Sergio and Stefano Schiavon. 2013. *Occupant Satisfaction in LEED and non-LEED Certified Buildings*. Building and Environment, Volume 68, October 2013, pp. 66 - 76. http://www.cbe.berkeley.edu/research/pdf_files/LEEDvsnonLEED2014-SchiavonAltomonte.pdf



Shared learning, better outcomes. Unless we measure and report critical aspects of building performance, it will be difficult to develop innovations aimed at improving their performance. Better building science should allow us to reliably predict the performance of a building at the planning and design stages, instead of devoting the efforts of the building science profession to fixing performance problems and conducting building forensics

The prospect of predicting building performance is encouraging if the scientific approaches adopted by other industries are brought to bear on buildings. The built environment remains among the final frontiers of systematically applying science and engineering to the delivery of consistently high quality products. Aside from industry inertia and a lack of political will, there is no reason the predictable performance of buildings cannot be achieved on a consistent basis. All future innovation is premised on being able to measure and share actual building performance information to better inform the design, construction, quality assurance, commissioning, operation and maintenance of buildings.

Important Next Steps

One of the desired outcomes for every Building Science Roundtable is a series of important next steps to be shared with our stakeholders. While the roundtable is confident that we can adequately define and measure building performance by the standards and protocols available today, without the next steps outlined below, Ontario's building industry will not be able to predict and deliver better building performance. This is crucial because buildings are relatively expensive and durable goods that society may no longer be able to afford to develop on a trial and error basis. Each building cannot be approached as a once-off prototype, as may be the case for the most exceptional architectural designs of extraordinary and idiosyncratic buildings. There are sufficient numbers of prototypical buildings, such as schools, offices and apartment buildings, that deserve to have their designs refined and more precisely contextualized to be responsive to local site and climate conditions. It is a fundamental premise that 21st century building science can be incorporated into our new and existing buildings through a series of coordinated initiatives.

Ontario Buildings Knowledge Base - It is urgently recommended to launch a government, industry, academic and consumer think tank to develop a framework to: 1) take inventory of existing building information; 2) integrate existing data (Statistics Canada, CMHC, MPAC, Tarion, municipalities, energy utilities, insurers, REITs, GIS, etc.); 3) gather information to fill gaps; and 4) provide a single gateway for online access to the assembled buildings knowledge base. The Ontario buildings knowledge base would be hosted by a public agency such as Infrastructure Ontario and its cost of operations paid for by a levy on all building permits and development charges.

Continuing Education for Design Professionals About Building Performance - Designing for performance requires the majority of Ontario's design professionals to upgrade their skills and knowledge in building science. Professional accreditation would be premised on lifelong learning and professional organizations need to partner with government and industry to fund the development and delivery of continuing education programs. Insurers of design professionals must encourage building science education through progressive premium structures.

Changes in Professional Practice to Deliver Acceptable Building Performance - Architects and engineers must advocate protocols for building design reviews, quality assurance throughout construction, whole building system commissioning and appropriate documentation to enable proper operation and maintenance of buildings. Insurers and warrantors of buildings and building professionals, should structure their premiums and bonds/security deposits such that adherence to best practices is financially rewarding to owners, constructors and design professionals.

Requirements in Building Codes for Design Review, Quality Assurance and Whole Building System Commissioning - Many of Ontario's leading professional practices have internalized best building science practices, and it is now reasonable to expect that building codes and protocols for building code enforcement can require third-party design reviews, quality assurance and commissioning of the whole building system, including envelope, HVAC, building and site services. Municipalities would become responsible for maintaining archives of drawings, specifications, consultant reports and complete documentation related to mandatory design reviews, quality assurance and commissioning. They would also observe a system of reporting to the Ontario buildings knowledge base, and expanding the current set of code compliant construction details that can be used for building permit submissions.

Measuring, Maintaining and Enhancing In-Service Building Performance - Building performance benchmarking and labeling are effective means of providing consumers with the means to make informed decisions about building choices. Government agencies responsible for reducing our carbon footprint and energy utilities that want to manage peak demand are among other examples of stakeholders that need measured building performance data to guide policies and programs. It is equally important for building owners and facilities managers to measure, maintain and enhance the performance of their assets to maximize service life and returns on their investments. By measuring and reporting improvements in the ratings and performance of their building portfolios, a positive feedback loop will encourage building owners to make investments in the sustainability and enhanced resilience of their assets.

Building Performance Research & Development for Better Performance Outcomes - How do we know if our buildings are performing better or worse than expected? Comprehensive post-occupancy evaluations started in the 1960s and have evolved into sophisticated techniques and protocols for specifically assessing occupants' perceptions of indoor environmental quality, and more generally, building performance. Protocols for building condition assessment were developed by the Institute for Research in Construction at the National Research Council of Canada in the 1980s. Computer modeling of energy, daylighting, natural ventilation and hygrothermal performance have become increasingly sophisticated over the past two decades. Recently, the use of unmanned aerial vehicles (UAVs), or drones, to perform thermographic and high-definition visual scans of building envelopes have been developed and demonstrated in Ontario. Despite numerous means at our disposal, the performance gap (the difference between expected and actual building performance) is not closing. The phenomenal growth forecast for the Greater Golden Horseshoe region over the next 25 years will make it difficult to close the performance gap without timely implementation of building performance information systems, and significant strategic investments in building performance R&D. The key to success is to focus on outcomes that go far beyond "To Code, On Time, On Budget."

Building performance assessments need to go beyond rating labels to include metrics and indicators that can be empirically validated and updated over the life cycle of the building asset.

We must be able to better define, measure and predict what really matters in the performance of our buildings, new and existing, if we hope to build a sustainable future across Ontario.

The building industry can only dream of fostering innovation if it embraces modern building science and joins the 21st century knowledge based economy. Leadership among stakeholders is needed to take the next steps toward improving the performance of Ontario's building stock. The building science community has the knowledge and expertise to contribute to what must be a transparent, inclusive and collegial collaboration among all the key stakeholders.

"It is an immutable law in business that words are words, explanations are explanations, promises are promises - but only performance is reality." Harold S. Geneen, CEO of International Telephone and Telegraph, 1959-1977.

Synopsis

Buildings, even speculative ones, are not commodities in the normal sense of commodification. They last a long time, are very difficult to dispose of other than by sale, and become an enormous financial liability if they must be taken out of service for repair. They are a cultural resource situated within a built environment that deserves our stewardship as much as the natural environment. Unlike less durable goods, such as automobiles, appliances and electronics that are replaced every few years by successive generations of innovative technologies, buildings tend to last for centuries. There will be no second chance to get it right and limited resources are pressuring us into getting buildings to perform as intended the first time they are constructed. Future generations cannot sustain the burden of crumbling buildings and infrastructure and for their sake we cannot afford to continue developing cheap buildings.

There is a genuine risk that Ontario will fail to adopt best information and knowledge management practices to support the delivery of building performance that positively contributes to the sustainable development of our built environment.

Periods of phenomenal growth, such as we are witnessing and are forecast to continue across the Greater Golden Horseshoe region, represent opportunities to launch strategic initiatives and make prudent investments in the future of Ontario.

There will never be a better time to allocate the necessary resources and to leverage that investment to close the building performance gap.

Too poor to be cheap. The buying power of Canadians has been steadily declining since 1971 and globalization means North Americans are no longer sufficiently affluent to build cheap and maintain expensive. We cannot afford to throw away all our buildings and get new ones. We have to build them right the first time, and then operate and maintain them responsibly. [Photo: Sean Marshall.]

Additional Information

The following information is available online and provides a number of insights and perspectives on building performance.

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[Photo: Ted Kesik.]