COMMERCIAL BUILDING INCENTIVE PROGRAM'S USE OF SIMULATION TO EVALUATE THE DESIGN OF NEW CONSTRUCTION ENERGY PERFORMANCE

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ABSTRACT

The objectives of the Commercial Buildings Incentive Program (CBIP) of Natural Resources Canada (NRCan) Office of Energy Efficiency are to bring about lasting change in attitudes and design practices of new buildings by in part demonstrating the economic and environmental benefits of energy efficiency. Since 1998, this program has assisted over 600 Canadian buildings achieve an energy consumption 25% better than Model National Energy Code of Canada for Buildings (MNECB) reference building. On average the buildings achieve 34% energy savings compared to the reference. These results are evaluated though building simulations tools EE4.CBIP (EE4) and EE Wizard.

Successful projects contain concrete information about what has been done to achieve improved performance. This discussion highlights some of the building energy saving performance results, as well, for the first time a highlight of the most significant measures implemented. Specifically a comparison of the percent savings versus an MNECB reference buildings, energy intensity by building type and average implementation rate of various significant measures are presented. These findings show that a combination of measures are considered in the design of energy efficient buildings.

INTRODUCTION

Commercial and institutional buildings in Canada, the focus of this paper, represent approximately 13% of both direct and electricity-related greenhouse gas (GHG) emissions, compared to 34% each for transportation and industry, 16% for residential and 3% for agriculture[1].

The commercial and institutional building sector represents over 1.1 billion gigajoules (GJ) or 314 billion kilowatt hours of annual energy consumption and 64 Mt of GHG emissions. Based on a total calculated floor space of 589 million square metres, average energy intensity in these sectors was estimated at 1.9 GJ per square metre excluding street lights in 2002. Space heating accounts for over 50% of energy consumption in buildings on average, followed by auxiliary equipment and motors (20 %), lighting (13%), water heating (7%) and space cooling (6%)[2]. A survey conducted for Natural Resources Canada (NRCan) by Statistics Canada demonstrated that new structures, including multi-unit residential buildings, are currently constructed at a rate of 5000 per year, representing 7.5 million square metres of floor space.

Retail and office space account for more than half of energy demands while schools, healthcare facilities and hotels and restaurants account for a further 25%. Due to a 26% increase in floor space since 1990 and other factors such as increased use of air conditioning and computers, energy use in this sector increased by over 30% from 1990 to 2002, but it is estimated that this consumption would have been 62.3 million GJ or 7.3% higher without improvements in energy efficiency[3].

NRCan is the federal department responsible for the sustainable development of energy, minerals, metals and forests. NRCan defines sustainable development as maintaining present benefits of resource development while fuelling innovation to create new benefits and ensure future quality of life3. This vision, which informs the activities of NRCan's many sectors, rests on three interdependent priorities: society, economy and the environment.

To reduce energy consumption and GHG emissions in buildings, a comprehensive approach must focus on renovating existing stock, on the smart design of new buildings and on the utilization of equipment that maximizes energy performance. For this purpose, the government has sets directions for commercial, institutional and government buildings. For new construction, the goal is a performance level 25% better than Canada's Model National Energy Code for Buildings (MNECB) by 2010.

In 1998, in keeping with its vision, NRCan created the Office of Energy Efficiency (OEE) and the Commercial Building Incentive Program (CBIP) to renew, strengthen and expand Canada's commitment to the adoption of energy efficient technologies and practices while decreasing the effects of global climate change. Specifically, the Commercial

Building Incentive Program (CBIP) works to encourage optimal energy efficiency in new commercial and institutional buildings constructed. To qualify as CBIP compliant, a building design must be 25% more energy efficient than the MNECB. If compliant, the proponent is given an incentive equal to twice the annual energy savings, up to $60k.

Between 1998 and March 2005, CBIP provided over $25 million in incentives to approximately 500 projects representing three million square metres of floor space. On average, projects are well above the 2010 goal with 35% energy savings over the MNECB totaling annual savings of over $25 million and $8 per square metre with a reduction of 0.1 Mt of GHG emissions. CBIP estimates it has influenced 10% of new building stock between 1998 and 2004, and expects to impact 20% of new floor space constructed in Canada in 2006. Internal data indicates that the average incremental capital cost of CBIP buildings is between 1.5 to 5.1%, and that buildings with energy performance of 40% better than the MNECB may not always show an increase in capital cost.

CBIP is rapidly gaining recognition as its uptake has increased significantly in the past two years. It has been instrumental in generating significant activity in the construction industry, particularly in building capacity of design professionals. Since LEED-Canada uses CBIP performance level as the benchmark for energy efficiency, labeling and alternative financing options are being further examined for their potential to generate incremental energy savings in new buildings.

CBIP staff also administer the Industrial Buildings Incentive Program as well as a market transformation strategy through a variety of instruments including financial incentives, development of simulation tools, promotion of integrated design practices, training of professionals, building labeling and partnerships. CBIP offers free modeling software to assist applicants with design and assessment of performance levels with respect to the MNECB.

SIMULATIONS, REVIEW PROCESS AND DATA COLLECTION

The OEE Web site makes advanced software freely available. For example, the EE4 simulation software estimates annual energy consumption for new buildings and has had 3000 registered users since 1998. The recently-developed Energy Evaluation Wizard (EE Wizard), a user-friendly and simplified modelling software for arenas and supermarkets with 500 registered users, allows the user to simulate the potential interaction between the refrigeration system, the building and the building's HVAC systems. The simulation logic includes in the reference and proposed buildings an assumption that certain minimum mandatory criteria of the MNECB are met such as insulation below slabs with imbedded radiant heating. The reader is referred to the EE4 modeling manual for a further explanation of the simulation details. The criteria for the reference building follow as closely as possible the MNECB – Compliance Supplement (CS).

To verify that a building is CBIP compliant, the simulation input data is cross reference with the structural, architectural, mechanical and electrial construction drawings and specifications, equipment manufacturer specifications and a checklist on conformance with meeting the MNECB/CBIP mandatory requirements. A list of most of the submission documentation can be found at oee.nrcan.gc.ca/newbuildings.

The submission review process has evolved since 1998 from when NRCan-CETC research staff reviewed submission to new review process where a network of simulation experts review files. The review verify input data with construction documentation and appropriateness of simulation strategy, such as zoning, with the simulation strategy. Reviewers correct simulation input data and simulation strategy, if required. A technical review report is then prepared which provides a description of the building envelope and HVAC system, energy consumption and cost information, a list of modifications performed by the review and after 2001 details of the significant energy conservation measures implemented in the buiding. A quality control review of the report findings is conducted by the CBIP technical advisor before a building is determined to be CBIP compliant.

The success rate of submission meeting CBIP requirement was approximately 85% in fiscal year 2004/2005. Non-compliant buildings are permitted to resubmit or provide NRCan with a copy of a change order for improvement extra measures added or compliance to an MNECB mandatory.

In all but a few exceptions, the reported percentage energy efficiency improvement relative to the MNECB reference excludes certain energy efficiency measures proposedby the applicants either because of simulation limitations, administrative difficulties in being able to verify the implementation of the measure or because they are considered standard practice in building design. It is important to beaware of these exclusions and the question of fuel scopematchingwhen the readerinterprets the findings reported. Further details can be found in the EE4 Modeling Manual. Examples include the following: building orientation, purchase of energy from a higher efficiency central system (verification difficulties), a building automation system or night-time setback (same scheduale is used for proposed and reference), below grade and slab insulation exceeding the mandatory (although these measures are important current simulation limitation do not credit), improved door U-value, wall/roof absorptivity, roughness and infiltration (set equal in proposed and reference with and infiltration rate of 0.25 L/s per m2), garage demand control ventilation (considered common practice), humidification (no credit is given for the use of heat and dessicant wheels). As well exterior lighting, process load and plug load improvements which are not included in MNECB are also excluded in CBIP. Renewables such as solar and wind are modeled using RETScreen and the reference cost is that for the utility that would have been the fuel choice if the renewables were not considered.

Finally, a prescriptive approach for compliance of buildings under 4,650 m^2, which allows the option of selecting a energy efficiency measure set bundles was also available. The intent of this approach was to off-set the additional cost of demonstrating compliance through energy simulation for CBIP for very small building. However only approximately 2% of submissions to CBIP choose to apply though the prescriptive approach and thus the data pool has less than 2% of buildings with energy measures reported from this compliance approach.

DISCUSSION AND ANALYSIS

Energy intensity comparison

At the time the data was compiled, CBIP represented buildings in all major commercial and institutional sectors. The percentage each sector respresented of the 500+ data pool were educational (33%), office building (19%), health care (19%), retail food stores (9%), retail (9%), multi-unit residential buildings (5%), recreational centers and arenas (1%) with a balance of 14% in other sectors such as industrial

Figure 1: Energy Intensity of Buildings

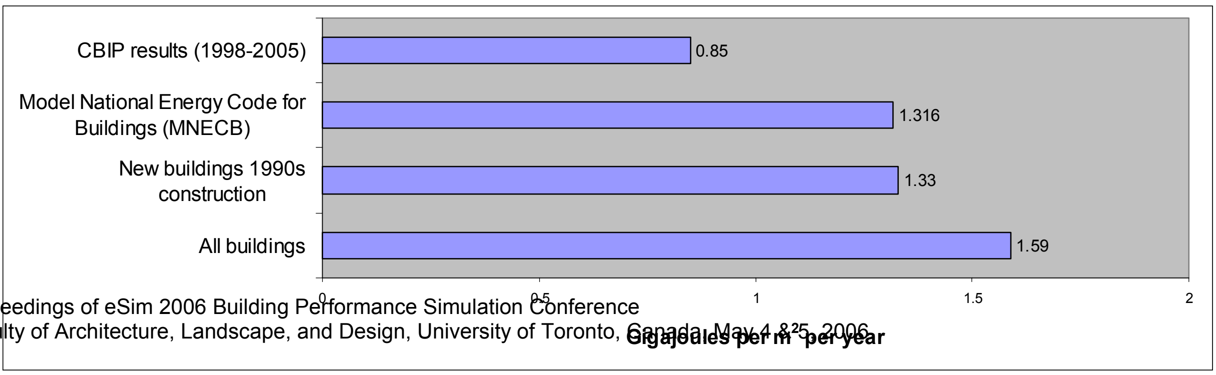

Figure 1 shows a comparison of the energy intensity in GJ/m^2 of an MNECB reference building, proposed design and typical new construction (1990s) practice. The typical construction practices are compared to CIBEUS study results. On average the 1997 MNECB reference building energy intensity is comparable to CIBEUS typical new construction intensity. The CBIP data was weighted by area allow it to be comparable to those of the CIBEUS study. It is interesting to note from this figure that the MNECB reference consumption (~1300 GJ/m^2) is comparable to typical construction practices of the 1990s.

The intensity data by sector, as shown in Figure 2, allows a similar observation to the summary comparison presented in Figure 1. In all sectors, the CBIP performance is lower than current design practices. However in the educational sector the difference between the 1990 intensity and that of the CBIP target are comparable. The MNECB reference consumption is generally lower that the 1990s reference consumption, except in the office and other sectors. The higher 1990s consumption is believed to be because of plug load and/or process loads in these buildings.

Significant Measures in CBIP Buildings

In the summer of 2005, the data from technical reviews of 312 projects were compiled in a Filemaker Pro database in order to obtain a general overview of the measures which are allowing these buildings to achieve higher efficiency compared to the MNECB reference. Within Natural Resources Canada, this database is the largest Canadian compilation of specific implemented energy efficient measures in the new institutional and commercial sector buildings.

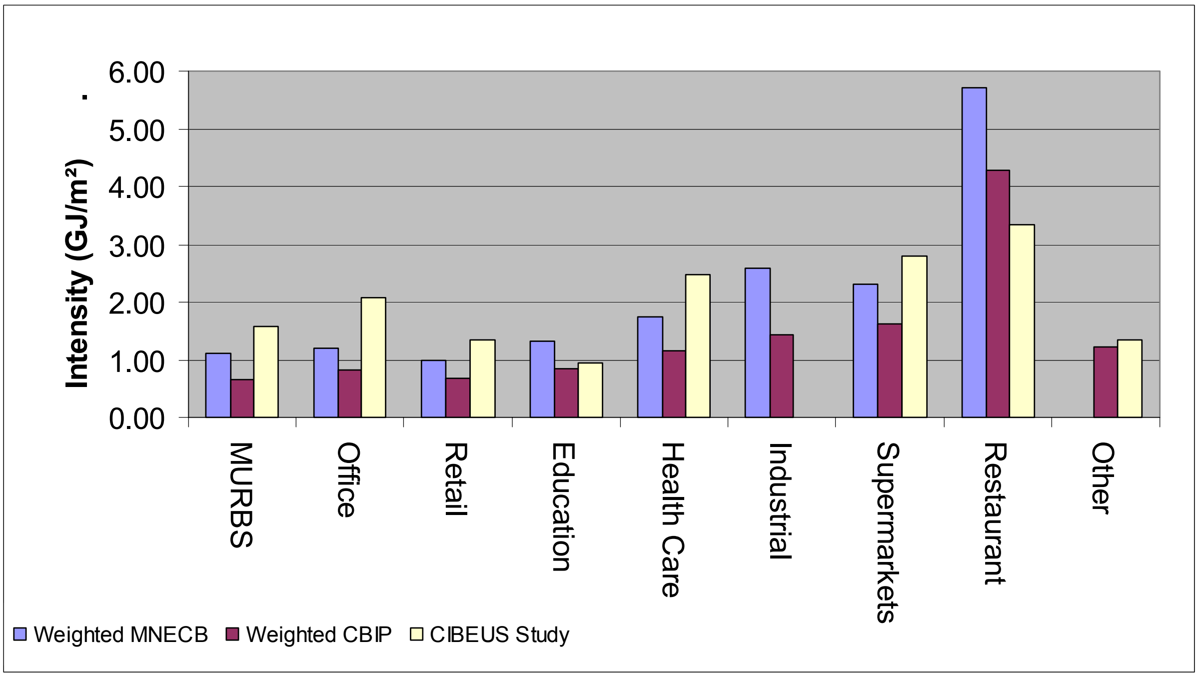

Figure 2: Energy Intensity of by Type

Effective designs combined conventional efficiency measures in building envelope, ventilation heat recovery, refrigeration, higher efficiency equipment and lighting for optimal energy performance. Innovative technologies such as solar walls, high efficiency condensing modular boilers, ground source heat pumps, enthalpy wheels and demand control ventilation are also considered. The percentage of projects selecting to implement various measures highlighted as contributing significantly to making projects acheive improvements over the MNECB are summarized below:

- 71% of buildings included efficient lighting technologies. The average lighting intensity was 12.4 W/m² (varied spaces).
- 60% installed heat recovery ventilators in their buildings.
- Better enveloppe elements were included in a large proportion of buildling. Specifially 46% installed better walls, 40% installed better roofs, 43% installed better windows
- 39% of building included boilers more efficient than the MNECB reference consumption of 80% efficiency. The average efficiency of installed boilers was 86%.
- 18% of all buildings included a form of heat recovery from refrigerations. This measure was applied in most CBIP compliant arenas and supermarkets but also in some restaurants.
- 16% installed more efficient domestic hot water boilers than the 80% MNECB reference. The average domestic hot water boier efficiency was 88.5%.
- 4% of buildings meeting CBIP compliant performance installed efficient higher performance chillers. These chillers were mostly of the centrifugal type.
- 6% of projects included ground source heat pumps.
- 2% used wind, solar or biomass as an energy source to obtain energy credit and reduced their proposed CBIP energy consumption.

This data helps demonstrate a significant energy reduction from the MNECB is attainable with existing technologies.

Most of these technologies must be considered in a primary design stage as part of integrated design approach to help ensure the proper measure is select. Retrofiting buildings for inclusion of these measures after construction is complete can either be impossible or cost prohibitive.

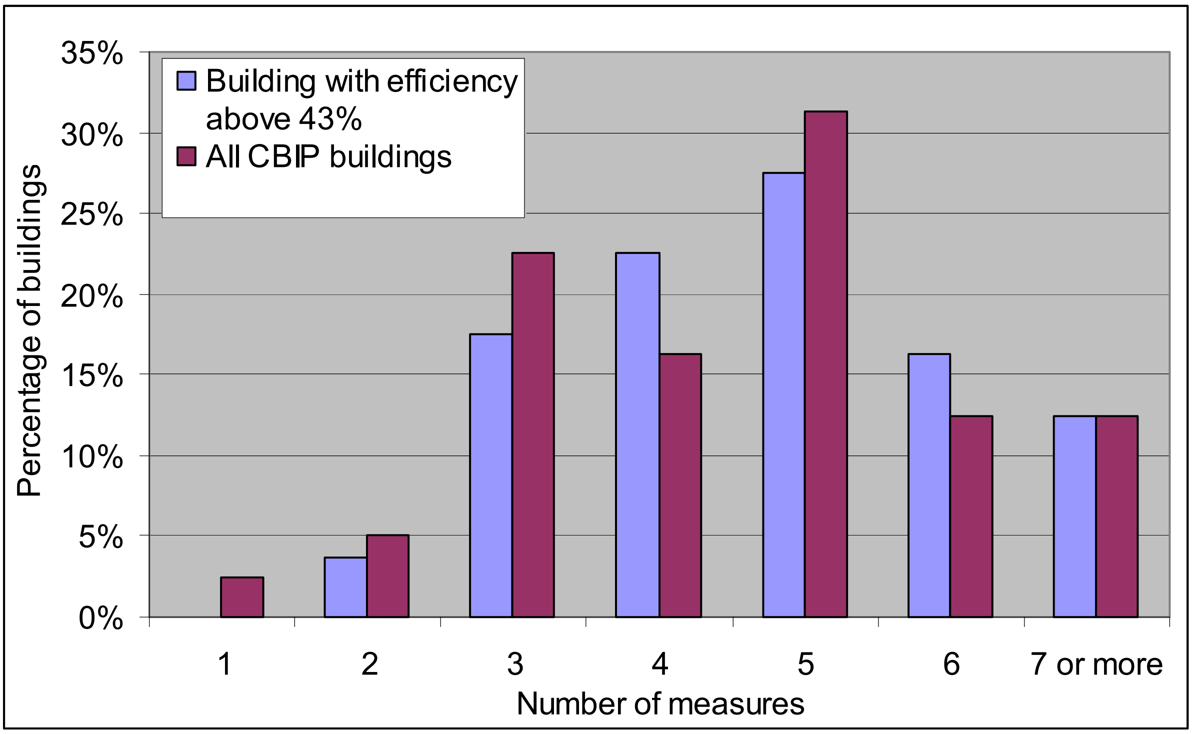

Figure 3: Number of measures implemented per building for all CBIP buildings and those with performance of 43% or more better than MNECB

Measures in Top Performing Buildings

An analysis was completed to see if the top performing buildings were utilizing different measures or a different number or measures than the entire stock of CBIP compliant buildings. Top performing buildings were thus designated as those that demonstrated performance of 43% or more better than the MNECB since these designs represented the quarter of compliant buildings. The top measures of these 80 buildings were very similar to those of the entire stock. The only notable expections were a significantly higher percentage of buildings installing better windows and heat recovery ventilators. There was also a significant drop in the percentage of buildings implementing refrigeration heat recovery. This drop is attributable to the fact that no retail food store were included in the top performers. The top performing buildings that include refrigration heat recovery were arenas or in the educational sector.

Also of note, only buildings with performances above 40% relative to the MNECB implemented renewable energy measures. This finding is consistent with recommendations of prior art in the field of green building design that renewable energy when included in the building also energy efficiency in the design.

The percentage of these top performing projects selecting to implement various measures highlighted as contributing significantly to making projects acheive improvements over the MNECB are summarized below:

- o 79% included efficient lighting technologies. The average lighting intensity was 10.3 W/m² (varied spaces).
- o 75% installed heat recovery ventilators
- o 41% installed more efficient boilers than the MNECB reference of 80%. The average efficiency was 89%, only 3% higher than the entire building pool.

- Better enveloppe elements were included in a larger percentage of buildings. Specifically 49% installed better walls, 41% installed better roofs, and
- 23% installed more efficienct domestic hot water boilers. Their average efficiency was 89%.
- 12.5% included ground source heat pumps.
- 5% installed refrigeration heat recovery.
- 4% installed efficient chillers.
- 3% used solar a energy source.

To conclude this comparison between the measures implemented in top performing buildings and that entire pool of CBIP compliant buildings, Figure 3 is presented. It provides a distribution plot of the number of measure implemented per building. On average 4.5 measures were implemented per building for the entire stock and for the top performer buildings 4.7 measures were implemented. Statistically this difference is not significant and point towards proper measure selection more important than quantity of measures implemented.

CONCLUSION

EE4 and EEWizard simulation tools have been useful in determining compliance of buildings relative to an MNECB reference. The energy intensity of CBIP compliant buildings was lower than that of 1990 buildings.

The work conducted also demonstrates that traditional and varied technologies are used to achieve CBIP compliance (consumption 25% less energy compared to an MNECB reference building). For the first time the most significant measures implemented in CBIP compliant buildings with the larger data set have been summarized. These measures include better lighting, better envelope, more efficient boiler and the use of heat recovery ventilators. For buildings demonstrating the top performance (43% or better than the MNECB reference) better windows and more heat recovery ventilation were found to be implemented in a higher percentage. Significant differences were not found in the number of measures implemented in top performing buildings and the typical CBIP compliant buildings pool. Results of this work, consistent with Canada's experience through NRCan's OEE, demonstrate that no single technology or program will reduce GHG emissions.

Futur work may analyse the regional and sectoral differences in energy measures being adopted and also a compare measures implemented based on building intensity rather than performance relative to the MNECB. Currently the data pool of 312 was judged to small for an acurate analysis at this time. Similarly with a larger pool of data an analysis of system combinations (such as heat recovery with make up air system) or disection of could be attempted. A study could also be conducted to compare the emphazise of building simulation research activity for Canadian commercial and institutional buildings to thedesign communities' need to simulate the most common energy efficiency measures being implemented.

NOMENCLATURE

MNECB – Model National Energy Code of Canada for Buildings
CBIP – Commercial Buildings Incentive Program

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