ACHEIVING MORE WITH LESS: VERIFICATION OF CANADA'S MODEL-BASED SCREENING TOOL FOR BUILDING ENERGY RATINGS

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ABSTRACT

Natural Resources Canada hosts an on-line "Screening Tool for New Building Design" that serves as a simplified modelling application. The Tool may be used to gauge qualification levels for the energy performance prerequisite and credit under the LEED® Canada-NC rating system. It also may be used to evaluate and rank proposed modifications to existing buildings, and to identify the mix of measures that results in cost-effective energy savings and a balanced design. To this end, the Yukon Government commissioned a study to verify the Tool's relative accuracy in comparison to a much more detailed computer modelling approach.

Overall, the Web Screening Tool compared well to the detailed energy performance simulations. The Tool was shown to be within ±2 LEED points (out of a possible 10) for 90% of the projects tested. The overall discrepancies on savings average +2.8% for energy use and -0.1% for energy costs.

This paper discusses the approach and results of this study. It also comments on where some of the largest discrepancies lie with use of the Screening Tool. Some of the most prevalent savings measures applied in a sample of efficient building designs are also highlighted.

INTRODUCTION

Several agencies in Canada are embarking on various sustainability initiatives aimed at influencing designers to adopt the principles and guidelines outlined in the LEED® Canada-NC Green Building Rating System (LEED). In support of this initiative, agencies like the Yukon Government are interested in providing a simplified approach for estimating eligibility and point awards for Credit 1 of the Energy & Atmosphere (EAc1) section of the LEED Canada rating system. LEED Prerequisite 2 (EAp2) and EAc1 are determined based on the modelling rules established by Natural Resources Canada's (NRCan's) ecoEnergy for Buildings program. With the relative lack of competent energy modellers and relative cost for smaller projects to pursue detailed simulation, many agencies are seeking simplified approaches that can be used more easily to determine potential energy savings.

Typically two approaches are followed for demonstrating building energy performance compliance: a “prescriptive path” and a “performance path.” Often building evaluation programs, such as Natural Resources Canada’s (former) Commercial Building Incentive Program (CBIP) and the U.S. Green Building Council's LEED 2.2, adopt both methods.

The prescriptive path method allows for building designs to adhere to a set of prescribed requirements, which in combination would meet the energy targets for that particular building type. NRCan, for instance, developed prescriptive bundles of measures for CBIP, which included measure sets for northern climates. The main benefit of the prescriptive approach is ease of implementation and compliance. The drawbacks, however, include lack of innovation by design teams potentially resulting in missed opportunities. Because the prescriptive bundles were so restrictive, CBIP found that few design teams followed this prescriptive method of compliance.

The second method of demonstrating energy performance is to evaluate the building’s entire energy usage by using a thermodynamic-based energy simulation tool. Advantages of this performance method are that it allows more flexibility in the design and it can apply to any building type. The disadvantages are that software programs available for showing building performance are complicated, time consuming, and require a relatively high level of expertise.

NRCan's "Screening Tool for New Building Design" (Tool) may serve as a simplified basis for the performance path method. The free Tool is hosted on the Office of Energy Efficiency's (OEE's) web site at http://screen.nrcan.gc.ca/ and provides users the means to rapidly model their design. The Tool automatically builds a comparative "Reference case" to gauge the relative energy performance following the ecoEnergy guidelines. It also provides a brief results report that highlights the overall energy and utility bill savings, along with the potential LEED qualification and EAc1 points. For most designs, the process of describing a building takes about 10 – 30 minutes.

The Screening Tool's energy calculations are derived from a transformed linear regression technique that effectively taps into the monthly end-use results from thousands of parametric hourly DOE2.1e (Winkelmann et al 1994) simulations. For a specific combination of building type, location, HVAC system type and heating fuel, the user defines his/her building based on a limited but key set of building characteristics. This allows users to enter values for a design, limited to relatively few inputs that most affect energy use. The inputs are submitted to the Web Tool, calculation performed for both the proposed and reference case models, and results returned to the Web browser within a few seconds, providing for very rapid feedback.

METHODOLOGY

To help the Yukon Government, and potentially other agencies, determine if the on-line application would provide accurate results for LEED screening, an energy analysis consulting firm conducted a verification analysis exercise to check the Screening Tool's relative accuracy in comparison to detailed energy performance compliance modelling. The verification effort involved entering a sampling of 29 projects into the Screening Tool, and evaluating how well the energy and cost savings compared to the original simulations. The identified projects were weighted toward buildings located in the Canadian North or in relatively cold climates, and included ten identifiable building types, ranging in size from 268 m² to 60,000 m². While these were the sizes of the buildings in the sample, the tool does not have a floor area restriction.

Note that the firm that directed the study also was the developer of the Screening Tool. This was beneficial since the company fully understood the details of how it worked, its limitations and how it should be most beneficially used for such an effort. However, we acknowledge that the verification is arguably skewed based on the developer's in-depth knowledge of the background assumptions for which other users would not be aware. In particular, a certain level of interpretation is required to distill the hundreds of characteristics that apply to an actual new building design for entry into the couple dozen inputs of the Screening Tool. Depending on the variances from the archetype building models for the Tool, users can inappropriately represent their building in the Tool. For this reason, the consulting firm employed an independent sub-consultant to review and input roughly 40% of the building projects used in this verification effort.

Project Selection

All building projects in the sample were new designs that were modelled based on CBIP protocols. Most simulations were completed using NRCan's EE4 energy performance compliance software, but a few older ones employed mainly the DOE2.1e hourly simulation engine used by EE4. As is often the case with EE4, several of the projects were finalized outside of the EE4 front-end software and completed using DOE2.1e.

We used projects that were readily available to us from internal modelling efforts or from verifications performed on behalf of NRCan for CBIP. Because of the limited scope and schedule, this study could not allow for a more statistically valid sampling, but the objective was to include as many projects as possible to get an initial indication as to the Screening Tool's relative accuracy. From direct access to well over a hundred projects, we identified 29 projects in the verification study. To make this study more relevant to the conditions in the Yukon, we focused on including projects from the Northern Territories or at least in relatively cold climates (nine of the projects were in the Territories and Nunavut).

Most of the projects were submitted to NRCan for evaluation under their CBIP program, but several were not submitted to NRCan due to timing with discontinuation of program incentives. Finally, about four projects were simulated for submission directly to LEED and were not reviewed by NRCan for various reasons. Of the selected projects, 10 different building type functions were represented, ranging in size from 268 m² to 60,000 m². These building types are listed below, along with the occurrence of each.

- Extended care (3)
- Hospital (1)
- Multi-unit Residential (1)
- Office, Large (4)
- Office, Small[1] (3)
- School (10)[1]
- Dormitory (2)
- Police Station (1)
- Recreation Centre (3)
- Shelter (2)

Note that the Screening Tool allows for direct evaluation of only a select list of building types, including extended care, hospital, multiunit residential, large and small offices, and schools. It does not include dormitory, police station, recreation centre, or shelter building types. Building types not directly available in the Tool were assessed using the closest building type(s)

[1] One building was a university building with half office and half school building type functions. Hence, the total number of represented building types was 30 rather than 29.

available (note that the Screening Tool allows for a building to be broken into two major building type blocks).

Data Preparation and Input

As the Screening Tool is a simplified modelling application, it requires significantly fewer inputs than the detailed energy performance models. Thus, the first step involved distilling the hundreds of building inputs from the detailed models to align with those required by the Screening Tool. This involved combing through the key modelling inputs and output reports to condense the data into a representative format for entry into the 30–60 inputs available through the Screening Tool.

The next step involved setting up the Screening Tool projects and transferring the condensed information to the respective projects. The project names were kept anonymous, with generalized IDs, to maintain the confidentiality of the specific CBIP/LEED project. The project results from both the detailed and Screening Tool simulations were then collected and saved to a workbook for comparative analysis. A sample results report from the Screening Tool is shown in Figure 1.

Figure 1. Sample Screening Tool Results Screen

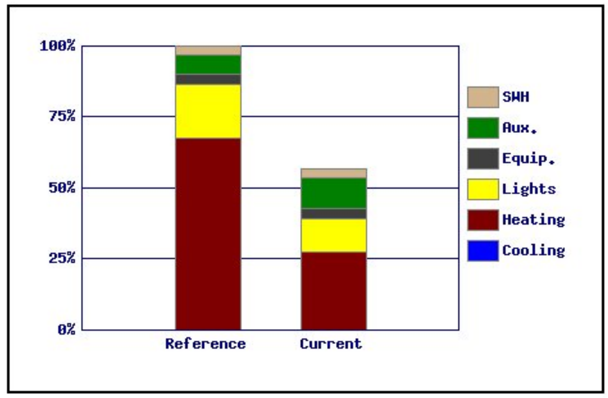
Current Design Performance

Annual Energy Use (GJ)		
Reference Building	7,822	
Your Design	4,444	
Energy Savings	**3,379**	**43.2%**
Annual Energy Cost Savings		**$79,955.66**
LEED® Canada **Energy & Atmosphere (EA)**		
Reference Building	$207,153.26	
Your Design	$127,197.60	
Regulated Energy Cost Savings**	**$79,955.66**	**(38.6%)**
LEED Canada EA Credit 1		**4 points**
Emissions Savings		
Carbon Dioxide (CO_2)	278,822 kg	

**Regulated energy costs exclude plug loads (equipment) for LEED.

Figure 1 continued

Annual Energy Use Comparison



Your Design

Annual Energy and Costs

End Use	Electricity kWh	Fossil Fuel Liters	Total Energy GJ	Costs
Cooling	600	0	2	$90
Heating	20,140	59,430	2,158	$48,428
Lights	256,298	0	923	$38,445
Equip.	75,137	0	270	$11,271
Aux.	230,240	0	829	$34,536
SWH	0	7,459	262	$5,699
Totals	582,415	66,889	4,444	$138,468

Reference Building

Annual Energy and Costs

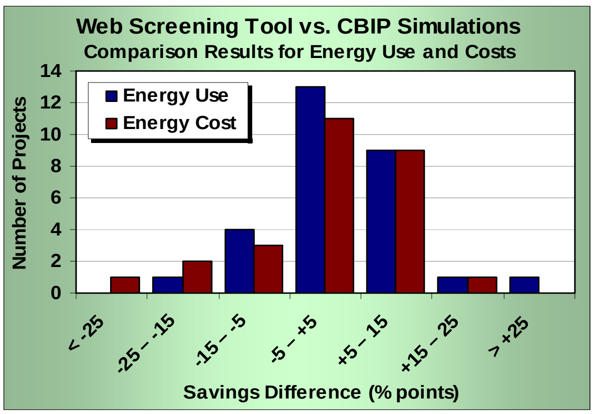
End Use	Electricity kWh	Fossil Fuel Liters	Total Energy GJ	Costs
Cooling	1,146	0	4	$172
Heating	42,643	146,565	5,296	$118,379
Lights	407,942	0	1,469	$61,191
Equip.	75,137	0	270	$11,271
Aux.	144,750	0	521	$21,712
SWH	0	7,459	262	$5,699
Totals	671,619	154,024	7,822	$218,424

RESULTS

Overall, the Screening Tool results compared favourably to the detailed energy performance simulations. This was true for both energy use savings as well as energy cost savings. Note that this is an important distinction because LEED requires savings on energy use of at least 25% to meet EAp2, but bases its point assignments for EAc1 on energy cost savings. (Energy use savings used for EAp2 applies only to the MNECB approach within LEED and stems from this being the requirement for the CBIP.)

Figure 2 shows the distribution of the relative differences between energy use and energy cost savings between the detailed and simplified approaches for estimating relative energy performance. As indicated in the figure, the Screening Tool predicted energy use saving to within ±15% points for 90% of the projects included in the verification assessment, and 45% of the projects were within ±5% points. On average, the Screening Tool predicted energy savings to within 2.8% points (higher) in comparison to the detailed simulations, with a standard deviation of 9.7% points.

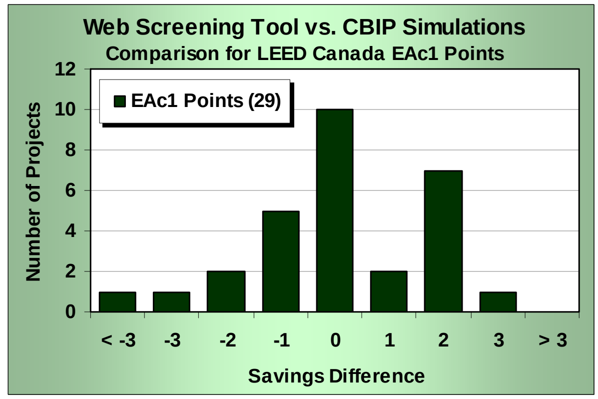
Figure 2. Energy Use and Cost Comparison



Energy cost savings, as calculated for LEED (which excluded plug loads) compared a bit less favourably. When comparing the Screening Tool EAc1 cost savings to those from the detailed simulation, 79% of the projects were within ±15% points and 38% of the projects were within ±5% points. Note that because two of the projects did not meet the 25% savings requirement to qualify for LEED EAp2, the Screening Tool did not report EAc1 cost savings. This is why Figure 2 has two fewer samples for the EAc1 cost savings results than for the energy use savings. On average, the Screening Tool predicted energy savings to within -0.1% points (slightly lower) in comparison to the detailed simulations, with a standard deviation of 10.7% points.

The EAc1 energy cost savings are used to calculate LEED EAc1 points. Figure 3 shows the results from comparing the points predicted by the Screening Tool versus the points that would have been (or were) awarded by LEED from the detailed simulations. As indicated in the figure, the Screening Tool predicted EAc1 point awards to within ±2 points for 90% of the projects included in the verification assessment, and 59% of the projects were within ±1 point. Over a third of the projects predicted the same number of EAc1 points. On average, the Screening Tool predicted EAc1 points to within 0.1 point (slightly higher) in comparison to the detailed simulations, with a standard deviation of 1.8 points.

Figure 3. LEED Canada EAc1 Point Comparison



Comparison Discrepancies

While the large majority of projects compared favourably in terms of predicted savings and EAc1 points, several projects did not fare so well. In investigating the projects that demonstrated more significant differences between the Screening Tool and detailed models, we found the following issues:

1. Projects with ground-source heat pumps (GSHPs) were particularly susceptible to having relatively high discrepancies. This was due to very significant differences in how the Screening Tool configures the Reference case versus how EE4 addressed this configuration. The MNECB modelling rules dictate that GSHPs with supplementary fossil heating are to be effectively compared to a Reference case with a fossil-fired boiler. The Screening Tool does this, as does EE4 for GSHPs serving distributed heat pumps. However, with the introduction of EE4 version 1.6, EE4 was inconsistently programmed to provide for an electric resistance boiler in the Reference case if over half the proposed heating load requirements were provided by the GSHP (which is nearly always the case). Moreover, EE4 introduced an error from DOE2 that allowed the electric heating efficiency to vary from about 80–95% instead of the 100% efficiency indicated by MNECB for electric heating. The net effect was that the effective fuel switch for the comparable Reference cases provided for a potentially significant discrepancy that can be magnified in the energy costs depending on the relative differences in electricity versus fossil fuel costs. The project with the worst comparison on energy use savings (26.2%), as well as the project with the worst comparison on EAc1 cost savings (-28.7%) and points (-5), exhibited this problem.

2. Projects where electricity rates were high in comparison to fossil fuel rates were also susceptible to having relatively high discrepancies. In many cases, the Screening Tool estimated absolute energy use for both the Proposed and Reference cases significantly higher or lower than in the detailed simulation. But in most of these cases, the relative differences cancelled each other out, providing for net savings that were relatively close. But if the local electricity costs were unusually high in comparison to fossil fuel costs, as often happens in remote Northern communities for instance, the relative EAc1 cost savings could become skewed. This is due to the relatively heavy "weighting" that the rates impose on the electricity savings versus fossil fuel savings. Several projects exhibited this problem (including the second worst project in terms of EAc1 cost savings comparison at -24.4%), with some remote Northern projects having local utility rates of over $1.00/kWh versus $0.87/liter for fuel oil.

3. Schedule differences could introduce discrepancies in many cases. The Screening Tool uses default MNECB schedules. If the detailed simulation applied different schedules, this could shift the relative end-use allocation in the comparative models. This issue was most prevalent in several school projects, where some simulators provided for more realistic reduced summer and holiday schedules (versus the weekly default MNECB schedules that apply for all times of the year). In these cases, electricity use was most affected because the Screening Tool includes summer operations (i.e., little space heating), which amplified EAc1 cost saving differences with the relative cost of electricity nearly always being higher than for fossil fuel.

4. Projects with relatively low auxiliary energy use cannot *presently* be represented with the Screening Tool. Hence, projects with mixed mode ventilation and/or displacement ventilation, for instance, may have their electricity use overstated in the Screening Tool. The second worst project exhibited this problem, which was exacerbated when combined with the issue of having relatively high electricity rates in comparison to the natural gas rates.

5. Building types that do not align with those provided by the Screening Tool provided for potential discrepancies and required careful thought as to which building type(s) would provide for the most representative approximation. This involved having an appreciation as to what the MNECB dictates for various building type functions, especially for lighting and distinguishing between residential and non-residential space uses.

6. Parkades, crawlspaces and attics sometimes caused discrepancies even if they were not included as part of the occupied floor area in the Screening Tool (as is the proper approach). In particular, if such a space was marginally conditioned and modelled with the fans always running (typically, not recommended), this skewed the energy use of the detailed simulation in comparison to the Screening Tool archetypes since they do not directly account for such spaces. In other words, the relative energy use likely would be understated with the Screening Tool if the area were excluded. However, if the area for semi-conditioned areas was included in the Screening Tool, the relative energy use tended to be overstated. This problem was minimized if the simulation was configured to provide for the cycling of fans (as is typical for how such spaces are actually controlled) to prevent having too much fan energy and possible heating of outside air. In one case, this was not done in the simulation. We consequently included the area in the Screening Tool project, which resulted in the project having the third worst comparison in terms of energy savings.

7. Demand charges for electricity can cause problems as the Screening Tool can provide for problematic predictions of peak demand on occasion. Hence, if high demand charges were entered (in comparison to the energy charges), this could exaggerate the relative cost savings – particularly for projects that varied significantly from the default values. For this reason, and for reasons of simplicity, we typically recommend entering an overall cost for electricity on a dollar per kWh basis and leaving the demand charges at zero.

Energy Efficiency Measures

When reviewing the detailed simulations for entry into the Screening Tool, we noted characteristics that contributed the most to the relative energy savings in comparison to the MNECB Reference case. For each project, we recorded up to five different energy saving measures that applied to each project from a list of standardized selections. The identified energy saving measures only included our estimate of the top five (if there were that many) that contributed the most to the savings in comparison to the CBIP Reference case. In most cases, if not all cases, for instance, roof insulation exceeds the minimum prescriptive requirement of the MNECB. But it was only included in our list of the top five measures for about 38% of the projects. Other measures either provided greater savings or the roof insulation level was low enough that its contribution to the incremental energy saving was minimal.

In general, mechanical measures provided for the largest energy savings. In particular, heat wheel heat recovery was the most prevalent measure—present in nearly half of the projects. More generally, exhaust heat recovery in all its forms were prevalent in all but two of the projects, averaging nearly 50% overall effectiveness for the 27 projects with heat recovery. Except for five projects with ground-source heat pump systems (and similar centralized heat pump systems), heat recovery typically provided for the largest individual energy savings—for the Northern projects, this definitely was the case.

Other measures that were quite prevalent included wall and roof insulation levels that significantly exceed Code. Lighting load reductions using lower lighting power densities and controls were also well represented. Significantly improved window thermal resistance and heating system efficiency gains rounded out the most frequent energy saving measures identified in the sample.

CONCLUSIONS

For the large majority of cases, NRCan's Screening Tool provided for a comparatively good representation of the relative energy savings one can expect from performing a much more detailed compliance simulation for LEED Canada purposes. However, the simplified tool could easily be used incorrectly (as with any simulation tool), providing for inappropriate comparative compliance results. For instance, a common mistake users might make which could have a very significant impact on the energy performance results is in the assignment of exhaust heat recovery. If the overall heat recovery does not account for fresh air from *all* systems and/or direct exhaust not returned for heat recovery purposes, the relative savings could be significantly overstated. Another common mistake is including the floor area for indirectly conditioned large spaces, such as crawlspaces and parking garages.

As highlighted in this report, the Screening Tool also has certain limitations and conflicts with NRCan's EE4 energy performance compliance software. Arguably the biggest discrepancy existed in the application of ground-source heat pumps (GSHPs) with supplementary fossil fuel heating. As previously explained, NRCan's EE4 energy performance compliance software effectively introduced this discrepancy with version 1.6, which improperly assigns an electric boiler to the Reference case for most cases. (Our recommendation has been to change EE4 to provide for an appropriate fossil fuel boiler in the Reference case with applicable GSHP systems. This is recommended because EE4 presently contradicts the MNECB Compliance Supplement modelling rules and EE4's own treatment of distributed heat pumps served by a GSHP system. Further, it is inconsistent with the secondary ASHRAE 90.1-1999 approach for LEED EAc1.)

The Screening Tool may be further improved through enhancements and upgrades, but it is important to maintain its relative simplicity and ease-of-use. Otherwise, the impetus for its continued use for rapidly evaluating energy performance issues, including for LEED Canada purposes, would diminish.

ACKNOWLEDGEMENTS

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