THE PRESCRIPTIVE PATH - ITS CONSTRUCTION AND PLACE IN THE COMMERCIAL BUILDING INCENTIVE PROGRAM

Doug Cane Andrew Morrison
Caneta Research Inc.
Mississauga, Ontario
caneta@compuserve.com

ABSTRACT

Hour-by-hour energy simulations using DOE 2.1E were employed to develop the prescriptive path guidelines for Natural Resources Canada's Commercial Building Incentive Program (CBIP). This paper will describe the approach taken to identify and compare current design practice and Model National Energy Code for Buildings (MNECB) requirements, to evaluate potentially cost-effective energy-efficiency measures, to screen measures for life-cycle cost, to bundle and evaluate measure sets (groups of measures), and extend the results to other locations across Canada. Results from each of the development steps are presented. The pros and cons of this approach to small building compliance as opposed to the performance path will be discussed.

INTRODUCTION

On December 15, 1997, Natural Resources Canada (NRCan) announced the implementation of a new program to encourage energy efficient construction in the commercial institutional sector. It was NRCan's stated objective to get more engineers/designers doing energy simulations and offering energy efficient alternatives to developers. Energy simulation was to become a routine part of building design. However, it was recognized that the energy saving and incentive available for smaller buildings may not be large enough in actual dollar terms to offset the additional costs of demonstrating compliance through energy simulation. Thus for buildings under 4,650 m^2 a novel prescriptive path was to be offered. Three months prior to the public announcement, NRCan, following a competitive tender process, awarded contracts to develop Technical Guidelines[1] for the new program. The initial Guideline developments were targetted to the office and hotel sectors. Later, Guidelines for the retail sector were initiated. In Fiscal year 1998 - 1999, Guidelines for the school and MURB (multi-unit residential building) sectors were also undertaken.

Our proposal outlined an approach, where through hundreds of simulations we would identify cost-effective energy measure sets (i.e. groups of measures) from which design teams could select. These measure sets would vary depending on local energy costs and building type and were to yield annual energy savings from the CBIP hurdle rate (25%) to as high as 50% relative to the MNECB[2]. Generally four or five measure sets were developed for each climate zone. Specific areas not impacted on by the individual measures in each set where to be in compliance with the mandatory and prescriptive requirements of the MNECB. This paper will describe the development of the Prescriptive path for multi-unit residential buildings and schools. A similar approach was used for other building sectors.

METHODOLOGY

While the development of the prescriptive path evolved over the two years, it essentially involved the following steps, most involving energy simulation using DOE 2.1E[3] and strict adherence to the MNECB Compliance Supplement[4] and CBIP rules:

- **establish current construction practice** - NRCan wanted to know how stringent current design practice was across Canada and to ensure there were no free riders or at least be aware of free riders. Current practice would also help set specific baseline energy criteria not prescribed by the MNECB.

- **compare current practice to MNECB** - for the building sectors of interest, the performance was compared between current practice and MNECB energy criteria using DOE 2.1E. Model buildings were selected that were representative of large and small buildings in each sector. Comparisons with published whole building energy use data were also made. This was to establish confidence in the DOE 2.1E model predictions used to develop the CBIP Prescriptive path and example results for the Performance Path.

- **pre-screen potentially cost-effective measures** - proposed energy measures were pre-screened against the following criteria - appropriate for building size; type of systems; climate; sensitivity to electricy to gas price ratio (i.e. heat pump systems only where warranted compared to fossil-fuel/electric cooling systems); whether CBIP credits could apply (e.g. outdoor lighting, elevators, energy management systems (EMS), suite lighting would not receive credit); whether DOE 2.1E could model the energy measure; whether compliance could be easily verified in practice; predicted annual savings and reliability or risk of not achieving the savings.

- **screen individual measures for Life Cycle Cost (LCC)** - DOE 2.1E simulations were undertaken for individual weather-sensitive measures, one at a time in isolation, taking into account fuel/electricity costs. These results were then extrapolated to other climate regions with other fuel/electricity costs. Capital and maintenance costs were developed using Means[5] and other sources for each measure and LCC analysis undertaken. Individual measures were then rank-ordered by discounted payback period for each building type and city, from lowest to highest LCC. The more economical measures were bundled together with others to exceed the CBIP hurdle rate of 25%.

- **perform bundle simulations and evaluate LCC** - this step involved doing DOE 2.1E simulations for both the large and small buildings, in each of the principal cities, in each climate region. Five energy efficiency measure sets or bundles for the small buildings and 3 energy efficiency measure sets, for the large buildings were undertaken. An additional set of DOE 2.1E simulations was undertaken for Yellowknife with different energy efficiency measures considered appropriate for that climate.

- **develop the prescriptive path and extend results to other locations in each climate zone** - this step involved organizing and laying out the simulation results into content for the prescriptive path for the Technical Guide and developing correlations of the DOE 2.1E results for each of the six climate regions to account for fuel/electricity prices and weather differences (i.e. different locations) within each region.

RESULTS

Current Practice Survey - A survey was undertaken of 20 design teams across the five principal regions to get their input on current or typical energy criteria for new buildings based on their knowledge and experience. **Vancouver** - Lighting load was generally higher than the MNECB. Fenestration, opaque walls and roofs had lower U-values in practice than in the MNECB. Outdoor air was higher in current practice than in the model code. In **Regina**, lighting and equipment loads were generally higher than MNECB prescriptions. Assumed occupant density was said to be higher as well. Fenestration, opaque walls and roofs had lower U-value in Regina than the Code prescriptions. Outdoor air was lower in Regina than required by MNECB. **Toronto** current practice energy criteria were often less stringent than the MNECB. Lighting and equipment loads were at Code, whereas fenestration, wall and roof U-values were sometimes higher. Again, as in Regina, outdoor air, in current practice was lower. In **Montreal**, lighting and equipment loads were similar to MNECB provisions, fenestration U-values were higher, wall U-values the same and roof U-values lower. Outdoor air was significantly higher than MNECB. Finally, in **Halifax**, lighting and equipment loads were higher than code, envelopes were more stringent in current practice than Code, but outdoor air was generally higher.

Current Practice and MNECB Energy Use - Current practice energy use in both schools and MURB sectors was found to be lower than MNECB by typically 10%, when energy criteria were applied to the model buildings and modelled in DOE 2.1E. Table 1 presents the whole building energy use resulting from the DOE 2.1E current practice and MNECB model runs.

Adjustments made to the MNECB or baseline models as a result of these comparisons were: lighting and equipment schedules were changed to reflect current practice findings; ventilation was added in garages with make-up air heated to 10 ºC and employing CO sensors.

Pre-Screening of Measures - An initial list of measures were drawn-up and screening criteria applied. A large number of energy measures were eliminated for one or more of the reasons stated in Methodology. These were (for MURBs):

- ventilation air pre-heat from solar wall;
- high efficiency ceiling fixtures/lamps in suites;
- reduce hot water distribution piping/circulation losses;
- use compact fluorescents and T-8 fluorescents in fixed fixtures in suites;
- ventilation timer control, to reduce outdoor air at night;
- high efficiency washer/dryers in common area;
- CO_2 sensors controlling suite outdoor air fans to reduce outdoor air during unoccupied periods;
- suite exhaust used for garage ventilation;

- solar water heater for pre-heating SHW;
- low flow showerheads.

Measures eliminated for schools, included:

- high efficiency outdoor lighting;
- waste heat recovery from grey water;
- high efficiency heat recovery chiller;
- low flow showerheads.

Screen Measures for Life-Cycle Cost - This task identified the most economic measures to include in the measure sets for the prescriptive path. None of the more economic measures yielded sufficient savings, by themselves, to exceed the CBIP 25% hurdle. However, when bundled with less economic measures an overall economic bundle resulted that exceeded the CBIP hurdle rate. It was rationalized that a measure was economic if the net present value of savings was positive over the life cycle. This ensured that CBIP yielded societal benefits by creating positive savings over the assumed 20 year measure set life. A discount rate of 10 percent was used in the LCC calculations as required by Treasury Board Guidelines.

Table 2 summarizes the rank-ordering of measures analyzed for small MURBs in Vancouver and Regina. Results for other cities were interpolated, on a degree-day basis, to save on simulation time.

Bundle Simulation and LCC Results - In this task, the measures found to be economic in the previous task were bundled and analyzed using DOE 2.1E. Four measure sets were formulated for each city, with each bundle containing between 3 and 6 individual measures. The resulting whole building energy savings and the discounted payback period for sample bundles are presented in Tables 3 and 4 for small MURBs and primary schools, respectively. Note that the discounted payback period is under 3.5 years for some qualifying measure sets in both sectors.

Extend Results to Other Locations - The DOE 2.1E simulations were restricted to the one representative city in each of 6 regions. There was a need to extend the results from this location to others within the same climate zone. These other locales could have different fuel/electricity costs and heating degree days. Linear best fit equations were developed for each measure between the total building energy savings in each representative city and the heating degree days for each representative city. This resulted in a form of equation as follows:

Adjusted Annual Savings ($/m^2) = $DDF \cdot (A \cdot E_{loc} + B \cdot F_{loc})/100$

Where:
DDF = Degree Day Factor (function of heating degree days (HDD) for design location);
E_{loc} = commercial run-off rate (i.e. last block) for electricity in design location (¢/kWh);
F_{loc} = commercial run-off rate for winter space heating in design location (¢/MJ);
A = correlation factor for electricity (kWh/m^2);
B = correlation factor for fuel (MJ/ m^2).

Values for DDF, A and B were provided for each measure set in each climate zone. The prescriptive path participant would only need to have a HDD value for his locale and the run-off electricity and fuel prices.

PRESCRIPTIVE VERSUS PERFORMANCE PATH

Pros - The CBIP prescriptive path is based on energy simulations performed by experienced analysts, featuring generally tried and proven energy measures, and is a relatively easy way to comply with CBIP requirements on small buildings (under 4,650 m^2). The quality control process is simpler as well, both for NRCan and the design teams.

For the uninitiated, the prescriptive path bundles raise awareness of the possibilities for energy efficient design. Today, we use the prescriptive path results to illustrate the paths to CBIP incentive at initial client meetings under the gas utility Design Advisory Program in Ontario.

The prescriptive path bundles provide example starting points (cookbook of ideas) to design teams, even when the performance path is chosen or mandatory (i.e. buildings over 4,650 m^2). In fact, NRCan developed a web-based screening tool from the prescriptive results to help design teams know the potential savings for their proposed measures.

The performance path is subject to errors when simulations are undertaken by the uninitiated. Energy simulation has a steep learning curve. At the outset of CBIP it was speculated that only 1 in 10 buildings used energy simulation. Designers used tools to determine loads and size equipment, but not to model energy use. Many CBIP teams have had to submit and re-submit simulation files seeking approvals. The process is time consuming and may discourage future participation and possibly impact on the long-term goal of encouraging energy efficient design.

Cons - The prescriptive path is felt by some to not encourage innovation. The prescriptive path does not encourage designers to learn simulation. Others have pointed out that design teams may like certain elements in a measure set, but not others. This is a barrier necessitating the addition of trade-offs that could be selected in lieu of particular measures, a feature that is not there now.

The prescriptive path many not make clear to the developer or design team that a measure set's application to their building will allow, for example, downsizing of the HVAC system components. This downsizing is important as it contributes to keeping incremental costs of the measure down. This was taken into account during the LCC evaluation of the measure sets but needs to be communicated to the user.

The prescriptive path still involves designer time and effort having to comply with the MNECB in areas not impacted on by measures in the selected bundle.

The prescriptive path approach may be counter to NRCan's objective by not engaging the designer enough to permanently change attitudes, methods and the way of thinking about energy efficiency in buildings at the time of design.

CONCLUSIONS

Many have a vested interest in the CBIP Performance Path including NRCan (the investment in the EE4 Software), the CBIP simulators (including the authors) across Canada, and the Gas utilities in Ontario. Simulations were subsidized in the early stages of the Program by NRCan and more recently, the DAP in Ontario provides free simulation support up to $7,800 to teams pursuing CBIP incentives. The prescriptive path also represents a significant investment by NRCan but has not benefited from the same market pull and subsidies that has been the case with the performance path.

The prescriptive path needs software development to shorten the design team time and effort to meet the MNECB requirements beyond the application of the prescriptive measures in the bundles. The same tool could be used in code compliance by design teams in the provinces and territories where the MNECB is eventually mandated.

Is it essential to move the design/development industry into energy simulation on every job? The answer is no. Today, because energy simulations are subsidized this is happening. In small buildings, the emphasis is in rapid design and construction, low initial cost and modest design fees - fees that cannot, in our opinion, support energy simulation. These buildings are ideally suited to the CBIP prescriptive path and there teams should be encouraged to use that path to compliance. If not, when the subsidies end, so could the practice of energy efficient design in small buildings in Canada.

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REFERENCES

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[2] Model National Energy Code of Canada for Buildings. National Research Council of Canada, 1997.
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[4] Performance Compliance For Buildings 1996. National Research Council Canada. May, 1997.
[5] Means Mechanical Cost Data, 1998.

Table 1: School and MURB Current Practice and MNECB Energy Use

School	Total Energy Consumption (1,000 ekWh)				
	Vancouver	Regina	Toronto	Montreal	Halifax
Current Elementary School	1,334	1,311	1,313	1,262	1,269
MNECB Elementary School	1,360	1,563	1,440	1,262	1,332
Current Secondary School	4,899	4,903	3,633	4,620	4,455
MNECB Secondary School	4,950	5,366	4,427	4,667	4,579
Current Small MURB	881	1,697	1,291	1,088	1,122
MNECB Small MURB	912	1,769	1,381	1,090	1,164
Current Large MURB	2,578	-	4,261	3,697	-
MNECB Large MURB	2,825	-	4,463	3,673	-

Table 2: Rank-Ordering of Measure LCC - Small MURB

Measure	Whole Building Percentage Savings	Discounted Payback Period (yrs.)
Vancouver		
Install a high efficiency building transformer	0.3 %	3.5
Air-to-air heat recovery (in suites) on fresh air (70% effectiveness)	4.7 %	6.5
Air-to-air heat recovery (whole building) on fresh air (60% effectiveness)	9.6 %	10.5
Two-pipe ground-source heat pump	1.6 %	18.1
Regina		
Common area lighting package	1.0 %	1.4
Daylighting in corridors, stair-wells and garage	0.1 %	1.8
Air-to-air heat recovery (whole building) on fresh air (60% effectiveness)	14.7 %	2.9
Install a high efficiency building transformer	0.3 %	3.0
Parking garage lighting package	0.2 %	10.7
Two-pipe ground-source heat pump system	31 %	18.9

Table 3: Sample Measure Sets - MURBs

City	Measure Set	Whole Building Energy Saving	Discounted Payback Period (yrs.)
Vancouver	- air-to-air heat recovery - low flow showerheads/fixtures - common area lighting package - wall and roof ΔRSI 0.9 above MNECB	25 %	8.7
Regina	- air-to-air heat recovery - low flow showerheads/fixtures - common area lighting package - wall and roof ΔRSI 0.9 above MNECB	29 %	3.5
Toronto	- overall fenestration U-values less than 1.37 W/m^2 - wall and roof insulated to ΔRSI 0.9 above MNECB - air-to-air heat recovery	29 %	11.4
Montreal	- air-to-air heat recovery - low flow showerheads/fixtures - common area lighting package - wall and roof insulated to ΔRSI 0.9 above MNECB - overall fenestration U-values less than 1.37 W/m^2	25 %	2.2
Halifax	- two-pipe ground-source heat pump - air-to-air heat recovery - common area lighting package - low-flow showerheads/fixtures	37 %	16.3

Table 4: Sample Measure Sets - Primary Schools

City	Measure Set	Whole Building Energy Saving	Discounted Payback Period (yrs.)
Vancouver	- air-to-air heat recovery - lighting power density of 11.5 W/m^2 - classroom/offices - low flow showerheads, fixtures and auto-off faucets	25 %	2.7
Regina	- air-to-air heat recovery - overall fenestration U-value less than 1.37 W/m^2	31.5 %	6.0
Toronto	- overall fenestration U-value less than 1.37 W/m^2 - lighting power density of 11.5 W/m^2 - classroom/offices - water-loop heat pump system	33.2 %	immediate
Montreal	- air-to-air heat recovery - overall fenestration U-value less than 1.37 W/m^2	26.5 %	2.6
Halifax	- air-to-air heat recovery - lighting power density of 11.5 W/m^2 - classroom offices - low flow showerheads, fixtures, auto-off faucets	27.7 %	0.1