EXTERIOR BASEMENT INSULATION FOR COLD CLIMATES: FURTHER PROOF OF THE NEED TO BUILD BETTER NOW

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ABSTRACT

Given housing costs, basements are now no longer just utilized as storage spaces, but are often utilized as part of the interior space. Unfortunately, poor moisture management across these walls often leads to mould and mildew growth and poor air quality in basement spaces. As well, basement walls are a substantial component of all heat loss through the building envelope. Considering these problems, and the associated heightened consumer expectations, there are increasing demands on the below-grade portion of the building envelope. This paper compares model thermal and moisture performance and the life cycle economics of exterior basement insulation for four locations across Canada (Halifax, Toronto, Calgary and Vancouver). For each location, three scenarios will be analyzed: one basement built to the prescribed minimum standards established by local building codes, one built to the Model National Energy Code for Houses, and a more sustainable option built to meet the higher thermal and moisture performance needs of tomorrow. Each of these basements will be analyzed and life cycle cost analyses will be carried out using various energy price inflation factors. Considering the relatively long life cycle of homes built today, this paper will show that, from an economic as well as from a performance point of view, there is a compelling need to build better basements now.

INTRODUCTION

> "Canadians are in a race against time to slow the potentially devastating environmental effects of global warming and acid rain caused by high energy consumption in the developed world… Our housing, although it is far more energy-efficient now than it was twenty years ago, still uses far more energy than the planet can afford."

These thoughtful observations, made more than 15 years ago years ago in an Ontario Ministry of Energy case study (The Advanced House, 1990), are even more important today. In spite of good intentions, Canadians have failed to break their fossil fuel dependency developed over the past century. This dependency has many implications; in the housing sector, rising energy prices are making current homeowners pay for past inadequate decisions. The housing industry is in a troubled state – energy *in*efficient homes continue to be built, condemning future homeowners to bear the burden of higher energy bills while the environment continues to be unnecessarily degraded. This paper will show that building better basements now, using exterior basement insulation, makes both economic and environmental sense.

There are many reasons to reduce energy use – all equally valid. Environmentalists believe it is important to reduce the impact of humans on the environment. In contrast, many homeowners adopt a purely economic point of view: reduce energy use to save money. As the cost of heating and cooling homes continues to dramatically increase, energy costs may soon become increasingly more important to homeowners. Given the world growth in the demand for energy relative to the supply of energy, such price increases are expected to continue long into the future. Homeowners may soon realize that, in addition to the initial capital cost of a home, operational costs are important.

Unfortunately, today, a fundamental challenge must be faced – many consumers assume that homes built to the minimum provided by building codes will be cost-efficient. Thus, the majority of our housing stock continues to be built to minimum code requirements. Just meeting the energy standards set by the building code will lead to the least initial capital cost. Unfortunately, this approach ignores the costs of operating the home and the resulting life-cycle energy demand! It is clear that just meeting the building code is, in many cases, short-sighted. By improving basement thermal insulation levels, costs of owning and operating homes can be reduced, life cycle energy can be reduced, and moisture-related problems can be minimized.

Many examples outlining the cost savings of better built buildings exist, including a case study conducted by the Ontario Ministry of Energy. This study found that an "advanced house" could lead to a reduction in energy use by 73% compared to a similar dwelling constructed to the local minimum building code requirements (The Advanced House, 1990). Similar findings related to basement insulation were reported in a 1992 study by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (Thermal Performance of the Exterior Envelopes of Buildings, 1992). The ASHRAE study determined that the use of RSI 1.76 (R10) full-depth insulation reduced basement heat losses by an average of 55% compared to a bare wall. So two questions can properly be raised: how much basement thermal insulation should be provided, and on which side of the wall should it go?

THE CASE FOR EXTERIOR INSULATED BASEMENTS

There exists a number of reasons why interior insulation has traditionally been the preferred choice over the exterior option. The principle reason is purely economic. Materials used for insulating basements on the interior cost about 2/3 less than insulating materials used on the exterior. Another reason is exterior insulation necessitates protection of the above-grade portion from impact damage in service – the "weed-whacker problem" (Yost and Lstiburek, 2002). During construction, builders typically have a difficult time providing protection of exterior exposed insulation. Also, the use of exterior insulation can lead to a need to shift the above-grade wall structure outwards to align it with the exterior of the foundation wall (i.e. the outboard side of the insulation). Finally, some studies have shown that exterior basement insulation is marginally less effective than its interior counterpart due mainly to the potential for thermal bridging at the top and bottom of the foundation wall (Kesik *et al*, 2001).

Yet internally-insulated basements are not necessarily better than externally-insulated basements. Internally-insulated basement walls are more likely to experience moisture problems. During the summer months, the internally-insulated foundation walls are relatively cool. These cool surfaces lead to a greater potential for warm, moist interior air to condense on the interior foundation wall surfaces. This increase in condensation potential often leads to the growth of mould that contributes to the musty odours often associated with basements. This increase in condensation potential can also lead to the decay of any organic materials such as wood members or the corrosion of steel studs in contact with damp foundation walls. As well, internally-insulated basements may be more susceptible to soil water ingress. Driven by either capillarity or hydrostatic forces, soil water may more easily enter an improperly designed and constructed internally-insulated basement wall. Thus, whether water enters the wall from the soil, or whether water from the interior condenses on relatively cool foundation wall surfaces, moisture and moisture-induced problems can lead to serious durability and health-related problems when basements are internally insulated.

Although there are design strategies that can be used to reduce the incidence of moisture problems when basements are internally insulated (Timusk et al., 1997), the use of exterior basement insulation will usually lead to warmer and drier walls. By placing the thermal insulation on the exterior of the basement wall, a natural drainage layer and capillary break can be provided. As well, this thermal insulation leads to warmer foundation wall surfaces, and reduces seasonal temperature variations. Thus full-depth exterior basement insulation is superior to the interior option in its ability to minimize the potential for thermal and moisture-related problems.

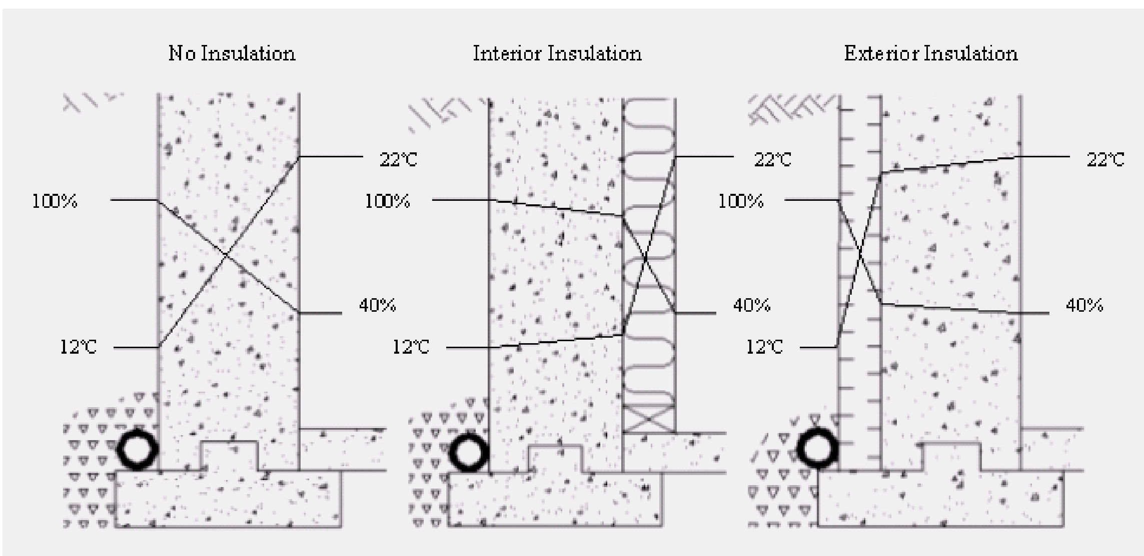

Figure 1. Temperature and Humidity Profiles for Three Wall Designs:
Summer Conditions 1.5m Below Grade in Toronto

Figure 1 illustrates the temperature and relative humidity profiles for three cast-in place basement walls: an un-insulated basement wall; an interior-insulated basement wall; an exterior-insulated basement wall. The benefits of exterior insulation are apparent:

- The insulation acts as a drainage layer that inhibits free water in the soil from coming in contact with the foundation wall;
- The concrete foundation wall is warmer, thereby reducing the relative humidity on the interior face and, consequently, the condensation potential;
- Moisture of construction can potentially dry to the interior of the building since relative humidity gradients are more favourable.

Exterior insulation can also be used in combination with interior thermal insulation. For example, consider a standard basement wall insulated from the interior with a typical RSI value of 2.1. The performance of this wall can be improved by adding exterior insulation with an RSI value of 1.0. Depending upon the climate, the dew point may still fall within the interior insulation plane during the heating season. However, this basement wall will still be warmer and drier than a basement wall that is only insulated on the inside. Not only is this "combined interior/exterior insulation" basement wall more thermally efficient but the potential for moisture problems is greatly reduced. Thus, the use of any exterior thermal insulation will improve the performance of the basement wall. For the homeowner, the use of exterior insulation is a wise choice since it will lead to a better indoor environment. For the builder, the additional cost of exterior insulation may be justified since the likelihood of moisture-related deterioration will be less, and, therefore, the potential for corresponding repair and warranty claims will be reduced.

METHODOLOGY

MODEL DESCRIPTION

The simulation analyzed three exterior basement scenarios for the cities of Halifax, Toronto, Calgary and Vancouver. An average-sized home was constructed and modeled using the Hot2000 (Version 9.21) software available from Natural Resources Canada. The energy demand was analyzed for the following three scenarios:

1. The average house built to the minimum local building code requirements.
2. The average house with the basement walls upgraded to the Model National Energy Code (MNEC) minimum requirements.
3. The average house with a more sustainable "better practice" basement wall construction comprising:
   - Insulating the full wall area on the exterior (to either the provincial building code or MNEC requirements, whichever was more stringent).
   - Mitigating thermal bridges at the foundation wall/above-grade wall interface as shown in Figure 2.

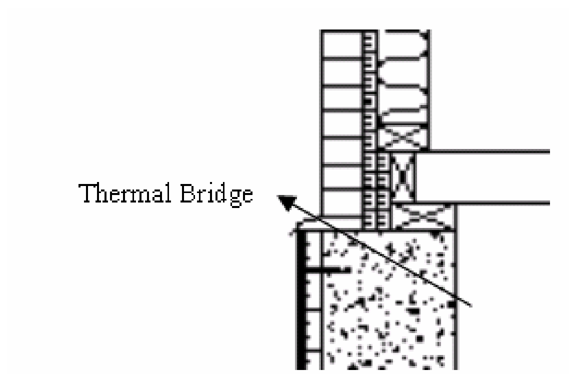

Figure 2. Typical Foundation Wall/Above-Grade Wall Interface
(Note the Location of Thermal Bridging)

Details of the "model" average house are outlined below:

- A two-storey square building with a full basement and a foundation 1.84m (6.04ft) below grade.
- An above-grade floor area of approximately $186m^2$ ($2000ft^2$).
- Equal window areas on the north and south faces.
- Equal window areas on the east and west faces, each with less window area than the north or south faces.

This "model" average house was the base case for all energy simulation runs. The only variables introduced were the foundation wall insulation values, and the area insulated. In all simulations, basement insulation was placed on the outside of the structure.

It should be noted that, in some locations, the insulation prescribed by the MNEC varied depending on the heating source used. Therefore, for all MNEC simulations, the fuel source was assumed to be natural gas.

MODELING RESULTS AND DISCUSSION

Table 1 outlines the basement requirements in the three scenarios for each city.

Scenario	Toronto, Ontario	Calgary, Alberta	Vancouver, British Columbia	Halifax, Nova Scotia
Provincial Code	RSI 1.41 (600mm)	RSI 1.4 (600mm)	RSI 2.1 (600mm)	No Prescriptive Requirement[1]
MNEC – Natural Gas	RSI 2.1 (Full Wall Area)	RSI 2.1 (Full Wall Area)	RSI 1.7 (600mm)	RSI 3.1 (Full Wall Area)
Better Practice	RSI 2.1 (Full Wall Area) & Thermal Break	RSI 2.1 (Full Wall Area) & Thermal Break	RSI 2.1 (Full Wall Area) & Thermal Break	RSI 3.1 (Full Wall Area) & Thermal Break

Table 1. Required Insulation Values and (Depth Below Grade/Area to be Insulated)

Figure 3 demonstrates the potential energy savings available by improving the basement insulation for all four cities; Table 2 summarizes these results numerically.

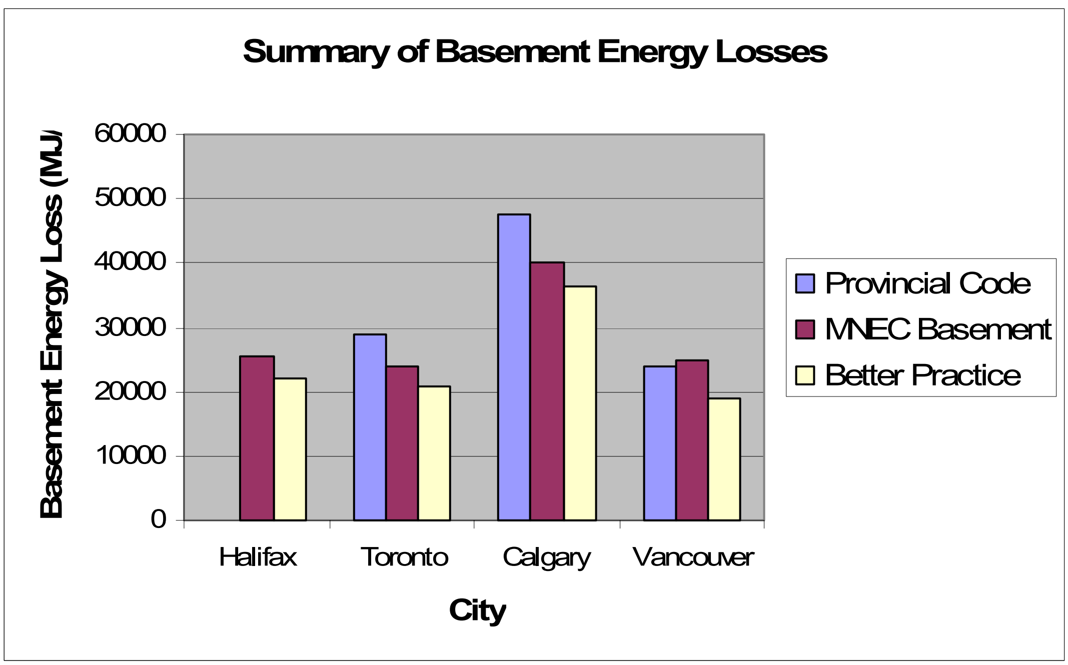

Figure 3. Basement Heat Loss by Location and Scenario

[1] Nova Scotia does not have a provincial building code. Instead, this province relies on the National Building Code of Canada (NBC). However, the National Building Code does not mandate a minimum value of thermal insulation.

Location	Scenario	Basement Energy Loss (MJ)	% of Total Energy Loss for House	Energy Savings (MJ)	Energy Savings (% of Basement Use)
Halifax	Building Code	-	-	-	-
	MNEC	25,442	30.6	-	-
	Better Practice	22,064	27.6	3,378	13.2
Toronto	Building Code	28,839	25.3	-	-
	MNEC	24,031	22.0	4,808	16.7
	Better Practice	20,984	19.8	7,855	27.2
Calgary	Building Code	47,663	26.9	-	-
	MNEC	40,023	23.6	7,640	16.0
	Better Practice	36,281	21.9	11,382	23.9
Vancouver	Building Code	23,954	28.0	-	-
	MNEC	24,735	28.6	-781	-3.3
	Better Practice	18,842	23.4	5,112	21.3

Table 2. Simulation Results for Energy Loss and Total Percentage

Given the climate in Alberta, the Alberta Building Code (ABC) was generally found to be less stringent than the other provincial codes evaluated. As expected, Calgary's relatively cold climate resulted in the largest energy loss value of the cities evaluated. While this is unfortunate from the perspectives of the homeowner and the environment, it provides great opportunities for improving energy savings through improved basement insulation, as shown in Table 2.

Although the total house percentage reduction in energy loss is smaller in Calgary than Toronto, the net energy savings is greater. This is due to the fact that the above-grade portion of the Calgary house is exposed to lower temperatures than those in Toronto, whereas the below-grade portions of these two houses experience similar conditions. In both cases, the soil moderates the below-grade temperatures. Consequently, the percentage of above-grade energy loss in Alberta is higher than in Ontario, thereby slightly reducing the overall effectiveness of basement insulation in Alberta relative to Ontario.

In contrast to the Alberta Building Code, the British Columbia Building Code (BCBC) is relatively stringent. Table 1 shows that the British Columbia Building Code required greater basement insulation than prescribed by the MNEC. This is reflected in the values shown in Figure 3 and Table 2. Considering the strict building code and the relative warm climate of Vancouver, the resulting lower overall energy savings are expected.

Nova Scotia does not have its own provincial building code. Rather, the National Building Code of Canada (NBC) has been adopted. The National Building Code does not specify minimum values for the levels of thermal insulation throughout the house. The National Building Code requirement states:

> "All walls, ceilings and floors separating heated space from unheated space, the exterior air or the exterior soil shall be provided with sufficient thermal insulation to prevent moisture condensation on their room side during the winter and to ensure comfortable conditions for the occupants" (National Building Code of Canada, 9.25.2.1, 1995).

As a result, due to the arbitrary nature of the requirements, a model house built to the provincial code was not completed. However, by building the entire home to MNEC insulation standards and then further upgrading the basement, some comparisons between the MNEC and the more sustainable alternative could be made. It should be noted that building the entire house to MNEC is a different approach than the one taken with the other locations (i.e. starting with provincial code requirements and only upgrading the basement). However, this approach provides reasonable results for the energy loss from the basement, regardless of the insulation level typically used in Nova Scotia.

In the near future, it may become possible to complete the comparison for Nova Scotia as the province is currently conducting a review to determine whether minimum insulation values should be established for energy conservation purposes (Ross, 2006). The results of this study clearly show that such measures would not only be beneficial to the environment, but would also be economically justified. However, because there is no separate provincial building code in Nova Scotia, the Halifax home was not included in the economic analysis.

ECONOMIC ANALYSIS

In order to perform the economic analysis, detailed construction cost data were obtained from a large tract homebuilder in the Greater Toronto Area. The data for this house model was factored to account for the size of the "average" house simulated in this study. A value for upgrading the basement walls to the better practice alternative was calculated for Toronto. This value was further factored for each city using standard industry metrics. Table 3 presents these values:

Toronto	**Calgary**	**Vancouver**
$1,185	$1,212	$1,200

Table 3. Incremental Cost to Upgrade from the Provincial Building Code to the Better Practice Alternative

Using the data from the simulation coupled with current local natural gas prices (May 2006), the energy costs and savings for upgrading to the sustainable alternative are presented in Table 4.

Location	Scenario	Gas Volume (m^3)	Cost	Savings
Toronto	Building Code	2299.2	$1,150	-
	Better Practice	2071.2	$1,036	$114
Calgary	Building Code	3595.8	$1,798	-
	Better Practice	3295.5	$1,648	$150
Vancouver	Building Code	1503.8	$752	-
	Better Practice	1379	$690	$62

Table 4. Energy Costs and Savings for Upgrading From the Building Code to the Better Practice Alternative

The question of whether to build better now becomes "Is the initial investment worth the annual energy savings?" Several financial indicators show that the common consumer consideration of "least capital cost" may not be the best choice when life cycle of the building is considered. These are summarized below in Table 5.

Indicator	Toronto Home	Calgary Home	Vancouver Home
Initial Investment	$1,185	$1,212	$1,200
Annual Payments*	$84	$86	$85
Annual Energy Savings	$114	$150	$62
Annual Cash Flow **	$30	$64	-$23
Internal Rate of Return ***	8.30%	11.57%	<0%
Simple Payback Period (Years)	10.4	8.1	N/A
Return on Investment (Year 1)	9.62%	12.38%	<0%

* Rate=5%, Period=25 years.
** Annual Cash Flow = Annual Energy Savings - Annual Payments.
***Internal Rate of Return gives the equivalent interest rate earned by the investment over its lifetime (25 years).

Table 5. Economic Analysis of Better Practice Upgrade.

With the exception of Vancouver, the results show that upgrading basements with exterior insulation makes economic sense. For example, in Calgary, if the homeowner chooses to pay for the upgrades by increasing mortgage payments, a positive annual cash flow of up to $64 can be generated through the resulting energy savings. Another persuasive economic indicator is the internal rate of return (IRR), calculated conservatively for a period of 25 years with no consideration for fuel cost escalation. The initial investment in the Calgary upgrade yielded an IRR of more than 11%. This is an extremely attractive investment given the relatively low risk of the option! Although Toronto did not have the same high return, the reality of today's energy and housing market is that energy conservation can put dollars back into the homeowner's pocket.

The Vancouver home was the only one studied that resulted in a negative return on the investment for exterior basement insulation. Given today's energy prices, it does not necessarily make economic sense to upgrade basements with exterior insulation in Vancouver beyond the building code requirements. However, it should be remembered that such insulation levels may make economic sense now when the basement is insulated on the interior. Interior insulation is a less expensive option. Since exterior basement insulation is generally not a practical retrofit measure, it should be applied when the building is first constructed. Given the superior moisture performance of exterior basement insulation systems, a combined interior/exterior system could be considered for Vancouver. Such a combined system would breakeven when the cost of the system falls to $900. Finally, it should be remembered that the economic analysis presented here does not account for the cost associated with moisture damage; adopting full-depth exterior insulation in British Columbia may still be justified since there will be a reduced risk of moisture problems.

In the above analyses for Vancouver, Calgary and Toronto homes, the price of fuel was assumed to increase at a rate equal to inflation; thus it was assumed that the price of fuel would remain unchanged in the future in relation to other expenses. Current and historical trends suggest that this assumption is conservative and even the most optimistic forecasters concur that it is reasonable to expect fuel prices to escalate ahead of inflation rates in the years to come. The above economic analysis for the Annual Cash Flow method was repeated for varying fuel escalation rates for the Calgary Home (taken above the inflation rate).

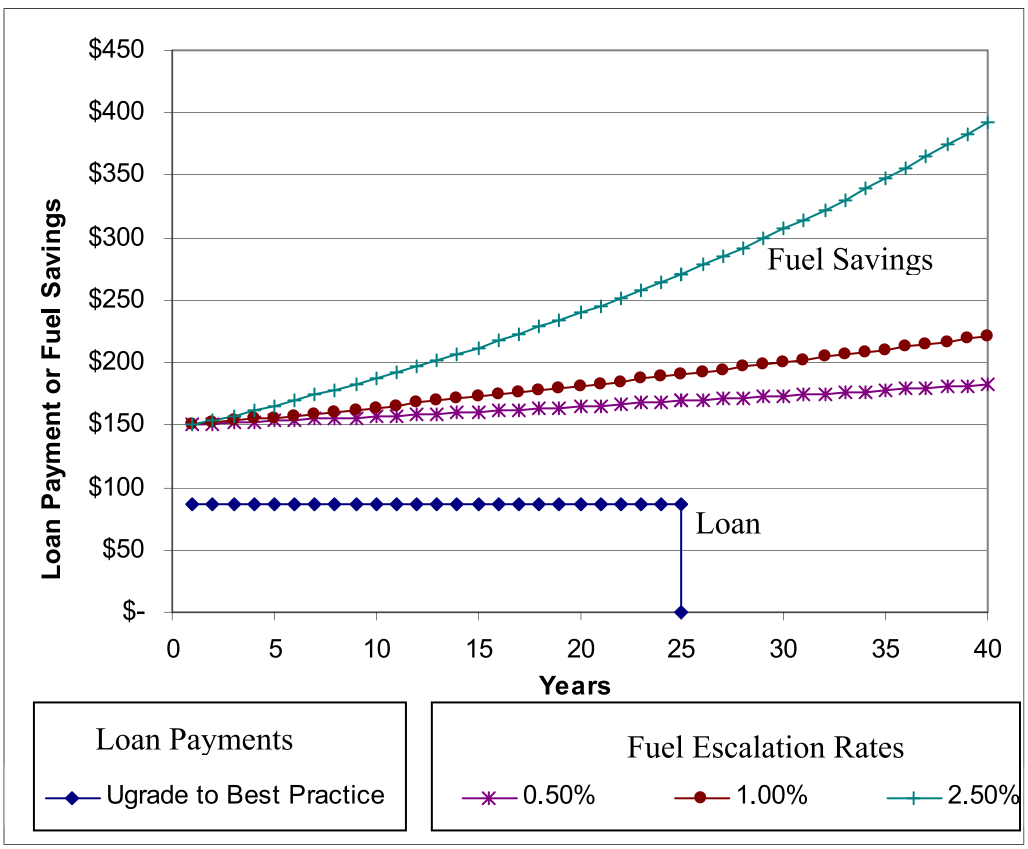

Figure 4. Fuel Savings vs. Time for Different Fuel Escalation Rates for a Calgary Home

Figure 4 shows the importance of building energy efficient buildings now because of the likely increase in operating costs that will be experienced in the future. Long after the homeowner has paid for the upgrade, the investment continues to return an ever-increasing energy cost savings. This shows that choosing the upgrade is the economically correct choice over the long term.

CONCLUSIONS/RECOMMENDATIONS

Vancouver is leading the way in Canada. The British Columbia Building Code already requires builders to build better now! Other provinces should use British Columbia as a standard and should consider adopting similar, more stringent requirements that properly account for operational energy used to heat homes. Although exterior basement insulation may not be economically justified in Vancouver today, exterior basement insulation already makes economic sense in Calgary and Toronto.

Many buildings being built today that just meet the building code are energy *in*efficient. By improving the levels of insulation energy can be saved, and the impact on the environment can be reduced.

Exterior basement insulation means lower energy bills for homeowners, and a comfortable, more durable home that is less likely to develop moisture-related problems. Given that placement of exterior basement insulation is really only economically viable during first construction, it should be strongly considered.

Unfortunately, the higher upfront costs of exterior basement insulation has, it seems, deterred builders from incorporating such measures. However, the conservative economic analysis presented here has shown that exterior basement insulation already makes sense now! Given the future costs of energy, can society really afford to delay building better buildings now?

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