January 2007 Technical Series 07-103

Economic Assessment of Residential Basement System Insulation Options

INTRODUCTION

This study updates the 1999 research, the *Economic Assessment of Basement Systems*, and is part of Performance Guidelines for Basement Envelope Systems and Materials, a joint project of Canada Mortgage and Housing Corporation (CMHC) and the National Research Council's (NRC) Institute for Research in Construction (IRC).

Since the 1999 study, fossil fuel energy prices in Canada have risen sharply and their escalation rate has consistently outpaced interest rates. As an example, the Bank of Canada rate over the seven years since the original study has averaged 3.76 per cent. The average annual increase in natural gas prices in the same seven years was approximately 11 per cent.

The 1999 study assumed an interest rate of four per cent and an annual energy escalation rate of one per cent for life-cycle cost assessments. This tended to undervalue the benefits of energy conservation in basements; positioned full-height basement insulation as being only marginally more cost-effective than partial height insulation; and, favoured lower levels of thermal insulation. As well, since 1999 the cost of residential basement construction also rose by about three per cent.

For these reasons, CMHC commissioned this study to update the economic assessment of residential basement insulation options to more accurately reflect the rising costs of basement construction and space-heating energy.

It is important to recognize that, as in the original study, a dollar value could not be put on a number of costs and benefits for various options. For example, in flood-prone areas, external insulation options may minimize the time and costs associated with damages and cleanup following basement flooding. Factors such as thermal comfort and potential for mold growth could not be economically assessed within this study, however, it should be recognized that such factors may significantly influence the value and marketability of housing.

OBJECTIVES

The study's primary objectives were:

1. To update material and labour construction costs for various types of basement systems available in the Canadian housing market;
2. To update energy prices and energy-price escalation rates to take into account expected trends in energy prices;
3. To include a larger basement model to accompany the smaller basement model used in the original study so that the effect of basement size could be compared;
4. To conduct a life-cycle economic assessment taking into account updated construction costs, energy prices and energy-price escalation rates; and
5. To prepare a report on the findings.

METHODOLOGY

This study employed a similar methodology to that used for the 1999 *Economic Assessment of Basement Systems* study. The main difference is that the 1999 builder survey was not repeated. Instead, the 1999 prices were adjusted by using 2006 material costs for thermal and moisture protection measures and applying a construction price index to the 1999 builder unit costs. Recognizing this difference, the steps taken in this study were as follows:

1. Research was undertaken into the construction price index from 1999 to 2005 using Statistics Canada data, which was subsequently compared with R.S. Means Residential Cost Data (1999 versus 2005) to validate the former.

The construction-cost inflation rate for Toronto, Ottawa, Halifax, Edmonton and Victoria was later applied to the 1999 builder unit costs to arrive at 2006 costs. (Note: The costs up to December 2005 were applied in February 2006 assuming a negligible increase for this relatively short time difference).

2. Material costs were surveyed in February 2006 to derive unit costs for the various thermal and moisture protection measures considered in the study. These 2006 costs were later combined with the inflation-adjusted 1999 builder costs to arrive at a total cost for each basement insulation option.
3. A survey of energy prices in February 2006 determined consumer costs by fuel price across the five cities considered in this study. Energy price trends and forecasts were subsequently reviewed to develop reasonable scenarios for price escalation.
4. A larger basement type was developed and modelled in BaseCalc™ so that annual space-heating energy demand for each insulation option was calculated across the five cities this study considered.
5. A new life-cycle cost assessment spreadsheet was assembled for analysis of three different scenarios of energy price escalation. The relationship of the discount or interest rate to the escalation rate for energy is critical when employing the modified, present-worth formula.
6. Following the life-cycle assessment, this report was developed to present the results and interpret their significance.

Because of regional variations in basement construction practices, it has not been possible to address every type of basement system in this study. However, the methodologies that have been developed may be applied by interested parties to yield specialized or localized answers to questions that commonly interest builders, consumers and society.

SOURCES OF INFORMATION

To analyze the various basement insulation options, this study considers the following data was collected and interpreted:

- Capital costs of basement systems and improvements
- Builder carrying costs and profit margins
- Energy prices and forecasts

A large number of computer simulations were also performed using BaseCalc™ to determine the energy performance of three basement classes:

- Class A-3 basements—full-height insulation with proper moisture protection
- Class B basements—partial-height insulation
- Class C basements—uninsulated cellars

The basements were in:

- Victoria
- Edmonton
- Toronto
- Ottawa-Gatineau
- Halifax

ENERGY PRICES AND CONSTRUCTION PRICE INDEXES

Energy and construction prices have risen sharply since 1999. Table 1 summarizes the data used in the current update study. It should be noted, by comparing with the 1999 energy prices listed in Table 2, the cost of fossil fuels has increased more dramatically than construction costs during this period.

Table 1 Energy prices, location factors and construction inflation for selected study locations

	Energy price ($/GJ) February 2006				Location factor	1999–2005 construction inflation
	Gas	Oil	Propane	Electricity		
Toronto	15.01	21.57	29.25	26.67	1.14	135.2%
Ottawa-Gatineau	15.01	22.09	28.85	26.67	1.11	156.5%
Halifax	N/A	23.14	40.71	29.44	0.98	129.7%
Edmonton	7.21	20.29	20.95	27.50	1.01	148.6%
Victoria	15.40	23.53	28.46	19.36	1.07	117.0%
					Average	**137.4%**

Table 2 Energy prices used in original 1999 study

	Energy price ($/GJ) 1999			
	Gas	**Oil**	**Propane**	**Electricity**
Toronto	6.98	9.76	16.42	25.64
Ottawa-Gatineau	6.98	9.76	16.42	20.44
Halifax	N/A	9.47	18.34	26.11
Edmonton	4.64	7.97	13.09	20.86
Victoria	6.98	10.56	16.83	17.00

The life-cycle cost parameters employed in the analyses attempted to portray three energy-price escalation scenarios, as shown in Table 3. A low, future-energy price escalation scenario reflected an historical datum when energy price increases were modest for several decades. The current scenario assumes that energy prices will continue to rise as they have over the past decade. The high scenario reflected the situation where current energy prices in Canada begin to approach prices in other developed countries.

Table 3 Life-cycle cost parameters used in 2006 study

	Future scenarios		
Parameter	**Low**	**Current**	**High**
Interest or discount rate	2%	3%	5%
Energy-escalation rate	4%	7%	12%
Study period (years)	30	30	30

These cost data, along with the BaseCalc™ space-heating energy simulation results, were subsequently applied within the life-cycle cost analyses of the three basement classes.

For more information on basement classes, see *Research Highlight—Occupancy-based Classification System for Design and Construction of Residential Basements*, Canada Mortgage and Housing Corporation, Technical Series 06-109, June 2006.

Table 4 Life-cycle cost assessment of large basement in Toronto – 80 per cent efficiency natural gas

Toronto—Natural gas 80 per cent efficiency, large basement										
Class A-3 Basement—Full-height insulation, unfinished										
Basement option	**R-Value**	**Annual GJ**	**Capital Cost**	**Annual energy**	**LCC of energy**			**LCC of Basement System**		
					Low	**Current**	**High**	**Low**	**Current**	**High**
Ext. XPS	12	17.6	$23,874	$330	$13,575	$18,869	$31,342	$37,450	$42,744	$55,216
Ext. Fibre	9.9	18.8	$23,200	$353	$14,501	$20,156	$33,479	$37,701	$43,356	$56,679
Ext. EPS	11.25	17.9	$22,916	$336	$13,807	$19,191	$31,876	$36,723	$42,107	$54,792
Ext. SPF	12	17.6	$25,080	$330	$13,575	$18,869	$31,342	$38,656	$43,950	$56,422
Int. Fibre	12	17.2	$20,928	$323	$13,267	$18,441	$30,630	$34,195	$39,368	$51,558
Int. Cell.	12	17.2	$21,019	$323	$13,267	$18,441	$30,630	$34,285	$39,459	$51,648
Int. Batt	20	14.3	$21,334	$268	$11,030	$15,331	$25,465	$32,364	$36,665	$46,799
Int. XPS	10	18.4	$23,182	$345	$14,193	$19,727	$32,767	$37,374	$42,909	$55,948
Int. EPS	9	18.9	$22,397	$355	$14,578	$20,263	$33,657	$36,975	$42,660	$56,054
Int. SPF	12	17.2	$25,271	$323	$13,267	$18,441	$30,630	$38,537	$43,711	$55,900
ICFs	22	13.0	$29,941	$244	$10,027	$13,938	$23,150	$39,968	$43,878	$53,091
Class B basement—Partial-height insulation										
Int. Fibre	12	23.5	$16,803	$441	$18,126	$25,195	$41,849	$34,929	$41,998	$58,651
Int. Cell.	12	23.5	$16,842	$441	$18,126	$25,195	$41,849	$34,968	$42,037	$58,691
Int. Batt	20	21.7	$16,978	$407	$16,738	$23,265	$38,643	$33,715	$40,243	$55,621
Int. XPS	10	24.3	$17,773	$456	$18,743	$26,053	$43,273	$36,517	$43,826	$61,047
Int. EPS	9	24.7	$17,435	$463	$19,052	$26,482	$43,986	$36,487	$43,917	$61,421
Class C basement—Uninsulated cellar										
Gas 80%	N/A	53.7	$15,575	$1,008	$41,421	$57,573	$95,629	$56,996	$73,148	$111,204

Table 4 summarizes a typical life-cycle cost assessment for a large basement in Toronto with 80 per cent efficiency natural gas heating. The maximum life-cycle costs for each class of basement are denoted by grey shaded values and the minimum values are denoted by white numbers in black cells. In all cases, the Class A-3 basement system is the most cost-effective under all future energy cost scenarios, when compared to a lower class of basement employing the same thermal-moisture protection option. In this study, it was found that the rankings for life-cycle cost-effectiveness are virtually identical for large basements and small basements. Table 5 summarizes the insulation options assessed in this study.

Table 5 Description of basement insulation options assessed in this study

Insulation option	Label	R (RSI)
1—Exterior extruded polystyrene—2 ½ in.	Ext. XPS	12 (2.11)
2—Exterior glass/mineral fibre—3 in.	Ext. Fibre	9.9 (1.74)
3—Exterior expanded polystyrene—3 in.	Ext. EPS	11.25 (1.98)
4—Exterior sprayed polyurethane foam—2 in.	Ext. SPF	12 (2.11)
5—Interior glass/mineral fibre—3 ½ in.	Int. Fibre	12 (2.11)
6—Interior cellulose—3½ in.	Int. Cell.	12 (2.11)
7—Interior glass/mineral fibre—5 ½ in.	Int. Batt	20 (3.52)
8—Interior extruded polystyrene—2 in.	Int. XPS	10 (1.76)
9—Interior expanded polystyrene—2 ½ in.	Int. EPS	9.4 (1.66)
10—Interior sprayed polyurethane foam—2 in.	Int. SPF	12 (2.11)
11—Insulated concrete forms (generic)	ICFs	22 (3.87)

The difference in annual energy costs between the best- and worst-performing Class A-3 basements in Table 4 is $111 (*ICFs vs. Ext. EPS*).

For Class A-3 basements, the most energy-efficient system is ICFs, and the most cost-effective system utilizes internal fibre-batt insulation with a nominal thermal resistance of R-20 (RSI 3.52).

Among the Class A-3 basements, the highest life-cycle cost systems vary depending on the energy-price escalation scenario. When energy-price escalations are low, the ICF option incurs the highest life-cycle basement system cost because the life-cycle energy savings do not offset the higher installed cost. Under the current energy-price escalation scenario, the exterior spray polyurethane foam insulation system incurs the highest life-cycle basement system cost because the R-12 (RSI 2.11) insulation level is suboptimal relative to its installed cost.

In the case of the high energy-price escalation scenario, the exterior fibre insulation system yields the highest life-cycle basement system cost because the R-9.9 (RSI 1.74) insulation level is suboptimal relative to its installed cost. This indicates that paying a premium for a higher performance thermal–moisture protection option may be justified in the long term when energy-price escalations are forecast to increase sharply. Life-cycle cost relationships were found to be similar across the five locations studied.

CHOOSING BASEMENT INSULATION

In view of the life-cycle cost assessments, and the related published work on basement performance problems, Table 6 presents preferable basement insulation options for new and existing homes.

Note that in all cases, full-height basement insulation is recommended over all other configurations, and it is also advisable to allow for some drying of construction moisture before applying interior insulation in new basements.

In the case of existing basements with moisture problems, it is practical to perform digging and drainage repairs from the outside; hence exterior insulation options may be preferable.

The selection of a suitable basement insulation option is largely governed by the intended use of the basement. Within the spectrum of site conditions encountered by builders across Canada, there can be large lot sizes and natural slopes that allow surface drainage away from the house in all directions, local soils can be free-draining and stable, the water table can be well below the footings and the local climate can be relatively dry most of the time.

In such conditions, a very basic basement configuration meeting minimum code requirements can perform adequately using any of the basement insulation options assessed in this study. Nevertheless, it is improbable that all of those favourable conditions exist at every construction site.

As a result, when the builder (and subsequently the homeowner) is dealing with one, some or many challenging conditions, consideration has to be given to additional measures that may be beyond the code

Table 6 Choosing basement insulation options for new and existing homes

Soil-sewer condition	New	Existing
Well-drained soil, no sewer backup problems	Any option*	Any interior option from 5 to 10
Poorly drained soil, poor site drainage	Exterior options 1, 2, 3, 4 and 11 preferred	Non-vapour permeable interior insulation options 8 or 10 recommended
Rising water table, some sewer backup problems	Exterior options 1, 2, 3, 4 and 11 recommended	Exterior options 1, 2, 3, 4 recommended
Flooding and/or chronic sewer backup problems	Exterior options 1 – 4 and 11 only	Exterior options 1, 2, 3, 4 only

* Refer to Table 5 for description of basement insulation options.

In existing basements, water leaks and sewer backup problems should be corrected prior to insulating. Refer to *Practical Measures for the Prevention of Basement Flooding Due to Municipal Sewer Surcharge: Final Report*, by T. Kesik and Kathryn Seymour, Canada Mortgage and Housing Corporation, 2003. (External Research Program Research Report) 95 pages.

For related information, refer to:

Molds in Finished Basements, 1996. Prepared by Scanada Consultants for CMHC.

Performance Guidelines for Basement Envelope Systems and Materials: Final Research Report. NRC-IRC, 2005.

minimum to compensate for those challenging site conditions. In most cases, exceeding minimum code requirements will be necessary to achieve acceptable levels of performance corresponding to modern consumer expectations, especially for fully finished, liveable basements.

CONCLUSIONS

Based on the findings of this update study, the following conclusions were drawn from the findings:

1. The assumption, made in the original study, that measures that were cost-effective in a small basement would be even more cost-effective in a larger basement has been proven correct. The life-cycle, cost-per-unit floor area for large basement systems is lower than for small basements because, for simple basement geometries, the basement envelope area does not increase linearly with floor area.

2. In all locations, irrespective of the thermal-moisture protection option selected, Class A-3 basements (full-height insulation with proper moisture protection) delivered the lowest energy and total life-cycle costs.

   Class B basements (partial-height insulation) and Class C basements (uninsulated cellars) are not cost-effective for consumers of housing under any energy-pricing scenario.

3. For all types and sizes of basements assessed in this study, the lowest life-cycle energy cost was associated with basements constructed using insulating concrete forms (ICFs).

4. For all types and sizes of basements assessed in this study, the lowest total life-cycle cost was associated with basements insulated internally, full-height to a nominal level of R-20 (RSI 3.52).

5. Where thermal bridging at the basement wall and floor header intersection is controlled, the annual energy demand and operating energy costs for externally vs. internally insulated basements are practically the same. Life-cycle costs for externally insulated basements are marginally higher than basements internally insulated to the same nominal thermal resistance. The difference is largely due to the higher installed cost of external insulation.

6. In exterior-insulated basements supporting masonry veneer, thermal bridging effects at the basement wall and floor header intersection are significant, resulting on average in a 20 per cent increase in the annual energy demand and operating energy costs over the corresponding case where thermal bridging is controlled. This study did not examine a complete floor slab and wall-system insulation wrap strategy, but for basements heated with in-floor hydronic systems, the control of thermal bridging may prove to be a critical for life-cycle cost-effectiveness.

7. There is considerable justification for reviewing the cost-effective levels of thermal insulation for basement systems in regulatory codes and standards governing residential energy efficiency in Canada due to the sharp escalation in energy prices recently experienced and forecasts of the continuation of this trend well into the foreseeable future.

CMHC Project Manager: Don Fugler

Consultant: Ted Kesik, Knowledge Mapping Inc.

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more ***Research Highlights*** plus a wide variety of information products, visit our website at

www.cmhc.ca

or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

Produced by CMHC 29-01-07

65346