RESEARCH REPORT

Development and Demonstration of a Life Cycle Costing Tool Applied to Green Technologies

Canada

CMHC SCHL
HOME TO CANADIANS

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) has been Canada's national housing agency for more than 60 years.

Together with other housing stakeholders, we help ensure that Canada maintains one of the best housing systems in the world. We are committed to helping Canadians access a wide choice of quality, affordable homes, while making vibrant, healthy communities and cities a reality across the country.

For more information, visit our website at **www.cmhc.ca**

You can also reach us by phone at 1-800-668-2642
or by fax at 1-800-245-9274.

Outside Canada call 613-748-2003 or fax to 613-748-2016.

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1-800-668-2642.

Development and Demonstration of a Life Cycle Costing Tool Applied to Green Technologies

Prepared for:

CANADA MORTGAGE AND HOUSING CORPORATION

By:

ATHENA SUSTAINABLE MATERIALS INSTITUTE

&

MORRISON HERSHFIELD LTD.

March, 2006

Disclaimer

This study was conducted for Canada Mortgage and Housing Corporation (CMHC) under the Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultants and do not necessarily reflect the views of CMHC.

Acknowledgement

The Athena Institute and Morrison Hershfield Ltd. would like to recognize the contribution of the following Steering Committee members who gave freely of their time and expertise to help guide this project.

Pierre Guèvremont, Natural Resources Canada, Ottawa

Sandra Marshall, CMHC, Ottawa

Luis de Miguel, CMHC, Ottawa (Project Coordinator)

Cameron Risdale, Cement Association of Canada, Toronto

Table of Contents

Executive Summary

For the residential building industry, the cost of constructing green buildings or incorporating green technologies, combined with the difficulty of marketing these higher performance homes and technologies, remains an issue that has effectively slowed the use of green building technologies in the residential market segment. The diffusion barrier arises on both sides of the equation – with the prospective buyer, and the developer/builder.

In order to aid the adoption of greener technologies, Canada Mortgage and Housing Corporation (CMHC) retained the Athena Institute (the Institute) in association with Morrison Hershfield Limited to develop a simple Excel© spreadsheet-based life cycle costing (LCC) calculator tool (and users' guide) to help builders and developers estimate the viability of green technologies applicable to single family homes and mid-size multi-unit residential buildings (MURBS). To further demonstrate the tool, the project team identified a set of 14 green technologies and prepared illustrative life cycle cost assessments of these technologies using the LCC calculator.

The overall intent of the project is to help builders and developers conduct life cycle costing evaluations of various green technologies, so they better understand and can better communicate these results to prospective clients. LCC is an economic method for evaluating project investment alternatives over a selected period of time. It is particularly suited to determining whether the higher initial cost of an investment is justified by reductions in future costs (e.g., operating, maintenance, repair or replacement costs). It can also be used to compare alternative investments with different initial and future costs.

The LCC tool is structured as a set of linked Excel© worksheets. A single worksheet functions as the input interface for the tool and provides a results summary of the life cycle cost calculation measures (e.g., net present value, simple payback period and return on investment) for up to three alternative investment scenarios. Additional worksheets relate to each scenario case and provide a level of transparency so that users may familiarize themselves with the more detailed cash flow results; however, knowledge of the worksheets is not required to run or use the tool. The tool is also capable of handling financing costs and periodic replacement costs of a complete system or its components over the desired investment period – up to 60 years.

To aid the user, the tool also contains a number of default values for general and energy price inflation (by fuel type). The various cells of the spreadsheet are also colour-coded to indicate values to be entered by the user, the values calculated by the tool, and default values contained in the tool which may be changed by the user.

Finally, the tool is structured such that it allows up to three investment scenarios to be considered side by side. This is useful when the user wants to compare a more conventional technology with a green technology, or conduct a sensitivity analysis around various variables pertinent to a green technology investment (e.g., changes in capital cost, avoided cost/price of conventional energy sources, or including and excluding financing costs, etc.).

The accompanying LCC users' guide documents each field to be completed by the user, provides sources for various data elements, and describes each of the results in simple terms to make LCC more accessible to the building community. The users' guide also contains an example LCC calculation, complete with the various inputs and results indicated by a screen capture of the tool.

In order to develop an illustrative list of green technologies for LCC assessment, a number of North American green building rating systems were reviewed to identify the various green technology themes advocated by these systems. Both the themes identified by the various rating systems and a list of specific technical upgrades addressing these themes were then circulated to the project's Steering Committee for input, discussion and eventual selection for LCC demonstration purposes. The 14 selected technologies were required to provide a tangible monetary return; as a result, the technologies can be broadly defined as either energy efficiency upgrades or water saving devices. The technologies assessed varied between more passive elements (e.g., increased insulation or improved air sealing in single family homes) and more complex technologies such as solar hot water heating, photovoltaic array installations and the incorporation of green roofs.

While only illustrative, the LCC assessments revealed that the more passive low cost investments offered a substantial return on investment. And while the more capital intensive and complex green technologies generally resulted in lower returns, they are for the most part on the cusp of becoming more viable investments — especially if energy prices continue to rise at rates experienced over the last three years.

Résumé

Le coût de construction de bâtiments écologiques ou d'intégration de techniques écologiques et la difficulté de commercialiser ces maisons et techniques haute performance ont effectivement eu pour conséquence de ralentir leur adoption au sein du secteur résidentiel. L'obstacle à leur diffusion se dresse dans les deux membres de l'équation, d'une part chez l'acheteur en perspective et d'autre part chez le promoteur ou le constructeur.

Dans le but de favoriser l'adoption de techniques écologiques, la Société canadienne d'hypothèque et de logement (SCHL) a confié à l'Institut Athena, en association avec Morrison Hershfield Limited, le soin de créer, sous forme de feuille de calcul Excel©, un outil d'estimation du coût global (ECG) (et un guide de l'utilisateur) destiné à aider les constructeurs et les promoteurs à évaluer la viabilité des techniques écologiques applicables aux maisons individuelles et aux collectifs d'habitation de taille moyenne. Pour mieux faire la démonstration de l'outil, l'équipe de projet a relevé une série de 14 techniques écologiques et préparé des estimations de leur coût global au moyen de l'outil de calcul.

La présente recherche vise de façon générale à aider les constructeurs et les promoteurs à effectuer des estimations du coût global de différentes techniques écologiques pour qu'ils puissent mieux en communiquer les résultats à des clients éventuels. L'outil de calcul ECG constitue une méthode économique d'évaluation d'options d'investissement au cours d'une période donnée. Il se révèle particulièrement tout indiqué pour déterminer si l'investissement initial élevé est justifié par des réductions des coûts ultérieurs (ex. : coûts d'exploitation, d'entretien, de réparation ou de remplacement). Il peut également servir à comparer différents investissements en fonction de divers coûts initiaux et ultérieurs.

L'outil de calcul est constitué d'une série de feuilles de calcul Excel© liées. Une feuille de calcul tenant lieu d'interface d'entrée fournit un résultat sommaire du calcul du coût global (ex. : valeur actualisée nette, délai de récupération et rendement de l'investissement) jusqu'à concurrence de trois scénarios d'investissement. Les autres feuilles de calcul se rapportent à chacun des scénarios et assurent un niveau de transparence si bien que les utilisateurs peuvent se familiariser davantage avec les résultats détaillés des mouvements de trésorerie; par contre, il n'est pas nécessaire de connaître la méthode des feuilles de travail pour faire fonctionner l'outil ou en faire usage. L'outil peut aussi calculer les coûts financiers et les coûts de remplacement périodique d'un système complet ou de ses composants au cours de la période d'investissement souhaitée, jusqu'à concurrence de 60 ans.

L'outil contient aussi, à l'intention de l'utilisateur, des valeurs par défaut concernant le taux d'inflation générale et celui du prix de l'énergie (selon le type). Les différentes cellules de la feuille de calcul comportent un code couleur indiquant ainsi les valeurs que doit inscrire l'utilisateur, les valeurs que calcule l'outil et les valeurs par défaut que contient l'outil, mais que peut modifier l'utilisateur.

Enfin, l’outil est structuré de telle sorte qu’il permet d’étudier jusqu’à trois scénarios d’investissement côte à côte. Il s’agit d’une caractéristique utile pour l’utilisateur qui veut comparer une technique classique avec une technique écologique ou encore mener une analyse de sensibilité de différentes variables associées à un investissement dans une technique écologique (ex. : modification du coût d’immobilisations, coût éludé/prix des sources d’énergie classiques, inclusion ou exclusion de coûts financiers, etc.)

Le guide de l’utilisateur de l’outil de calcul ECG donne des renseignements sur chacun des champs que doit remplir l’utilisateur, établit la source de différents éléments de données et fait état de chacun des résultats en termes simples pour rendre l’outil davantage accessible aux intervenants du secteur de la construction. Le guide de l’utilisateur contient également un exemple de calcul ECG, accompagné des différentes données d’entrée et des résultats indiqués par une saisie d’écran.

Dans le but de dresser la liste des techniques écologiques se prêtant à l’outil de calcul ECG, un certain nombre de systèmes de cotation de bâtiments verts, employés en Amérique du Nord, ont été étudiés en fonction des différents thèmes qu’ils préconisent. Les thèmes relevés par les différents systèmes de cotation et la liste d’améliorations techniques précises visant ces thèmes ont ensuite été diffusés auprès des membres du comité directeur en vue de connaître leurs impressions, de discuter de l’outil et d’arrêter un choix final pour les besoins de démonstration de l’outil de calcul ECG. Les 14 techniques choisies étaient requises pour offrir un rendement réel; en conséquence, les techniques peuvent se définir soit comme des améliorations sur le plan de l’efficacité énergétique ou des dispositifs économiseurs d’eau. Les techniques évaluées allaient d’éléments passifs (ex. : ajout d’isolant thermique ou raffermissement de l’étanchéité à l’air de maisons individuelles) jusqu’à des techniques complexes comme le chauffage solaire de l’eau, l’installation de panneaux photovoltaïques et l’aménagement de toits verts.

Offertes uniquement à titre indicatif, les évaluations menées à l’aide de l’outil de calcul ECG ont révélé que les investissements dans des techniques passives de faible coût se traduisaient par un rendement appréciable. Bien que les techniques exigeant beaucoup de capitaux et les techniques écologiques complexes donnent généralement lieu à des rendements moindres, elles sont pour la plupart en voie de devenir des investissements davantage viables, surtout sur le prix de l’énergie continue d’augmenter au rythme des trois dernières années.

CMHC SCHL

National Office
700 Montreal Road
Ottawa ON K1A 0P7
Telephone: (613) 748-2000

Bureau national
700 chemin de Montréal
Ottawa ON K1A 0P7
Téléphone : (613) 748-2000

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le résumé a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

Centre canadien de documentation sur l'habitation
Société canadienne d'hypothèques et de logement
700, chemin Montréal, bureau C1-200
Ottawa (Ontario)
K1A 0P7

Titre du rapport: ____

____

Je préférerais que ce rapport soit disponible en français.

NOM ____

ADRESSE____
rue App.

____
ville province Code postal

No de téléphone (   ) _____________

1 Introduction

For the residential building industry, the cost of constructing green buildings or incorporating green technologies, combined with the difficulty of marketing these higher performance homes and technologies, remains an issue that has effectively slowed the use of green building technologies in the residential market segment. The adoption barrier arises on both sides of the equation – with the prospective buyer and the developer/builder. In order to aid the diffusion of green technologies, Canada Mortgage and Housing Corporation (CMHC) retained the Athena Institute (the Institute) in association with Morrison Hershfield Limited to do the following:

1. develop a simple Excel© spreadsheet life cycle costing (LCC) calculator tool (and users' guide) to estimate cost/saving and payback of green technologies applicable to single family homes and mid-size multi-unit residential buildings (MURBS); and
2. develop a list of ten to fifteen green technologies to be considered by the Project Steering Committee, with ten of the technologies to be ultimately chosen and assessed using the LCC calculator developed above.

The overall intent of the project is to help builders and developers conduct life cycle costing evaluations of various green technologies, so they better understand and can better communicate these results to prospective clients. LCC is an economic method for evaluating project investment alternatives over a selected period of time. It is particularly suited to determining whether the higher initial cost of an investment is justified by reductions in future costs (e.g., operating, maintenance, repair or replacement costs). It can also be used to compare alternatives with different initial and future costs.

1.1 Report Structure

The remainder of this report is structured as follows.

Section 2 briefly describes the development and capabilities of the LCC tool and the accompanying users' guide.

Section 3 discusses the methods for identifying and selecting the green technologies to be assessed using the tool.

Section 4 presents the individual green technology case studies – technology description and application, key assumptions and costing information and LCC results.

Appendix A provides a more lengthy overview of the RETScreen integrated decision support software – a software that influenced the development of the LCC calculator. We also used RETScreen to complete some of the green technology case study assessments.

Appendix B contains screen captures of the LCC Calculator showing inputs and results for each of the illustrative case study assessments.

Appendix C contains the users' guide to accompany the electronic version of the LCC Calculator tool.

2 LCC Tool Development and Capabilities

2.1 Introduction

The Institute has previously developed various life cycle costing frameworks and tools. While building on this knowledge, we also realized that other similar tools already exist that could complement or, in some instances, be used in place of any LCC Calculator we arrived at for this project. For instance, the application of renewable green technologies (e.g., solar and wind) is highly dependent on geographical location, orientation and prevailing weather, and having access to such information in concert with an LCC tool would certainly make any economic assessment easier. These are the kinds of factors taken into account by RETScreen International[1], which has developed a tool that is capable of evaluating the energy production, life cycle costs and greenhouse gas emission reductions for various types of renewable energy technologies. In the process of developing the LCC Calculator, we often looked to RETScreen as a guide for its development. We also highly recommend using RETScreen's integrated software when assessing the use of renewables where site-specific orientation or climate information is required to generate reasonable results.

The next sub-section briefly summarizes the renewable technologies that RETScreen is capable of assessing and its methodology for completing an assessment. Following that we describe the capabilities and parameters of the simplified LCC tool we developed for this project and the various measures it supports.

2.2 RETScreen Tool

The **RETScreen International Clean Energy Project Analysis Software** is a unique decision support tool developed by Natural Resources Canada in partnership with a number of international agencies. The software, provided free of charge, can be used world-wide to evaluate the energy production, life cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs). The software also includes product, cost and weather databases, and a detailed online user manual.

Despite all the help (on-line user manual provided), on-line links to manufacturers and weather data, the knowledge base required to complete a pre-feasibility analysis is still extensive and beyond the lay knowledge of a typical builder/developer in consultation with a potential consumer of one of these renewable technologies. But due to the weather-related specifics of these renewable technologies (e.g., wind and solar), RETScreen offers the most efficient and effective method for sizing up the applicability

[1] More information on RETScreen International and its integrated support tool is available at www.retscreen.net.

of these technologies. See Appendix A for a more complete description of the RETScreen software or visit the RETScreen web site for additional information and case studies.

2.3 CMHC LCC Calculator Development and Capabilities

The initial guidance concerning the tool's development can be summarized as follows: "Develop a simple Excel© spreadsheet life cycle costing calculator to estimate cost/saving and payback of green technologies for single family homes and multi-unit residential buildings (MURBS) with emphasis on MURBS. The Calculator is to take account of expected initial, recurring (maintenance and replacement), and disposal costs to the extent possible. The calculator will also be capable of extending the analysis over a suitable time period to capture all relevant effects in a discounted cash flow analysis (e.g., 60 years). The output from the tool will be numerical, with the potential for a graphical display". Although the project's steering committee emphasized development of an easy-to-use tool, they also wanted it to be rigorous enough to account for various parameters that would need to be considered when applying a life cycle costing methodology to green technologies and assessing their viability.

The overriding backdrop to the tool's development is the understanding that the residential industry does not usually have a long-term relationship with its clients, nor does it typically employ an integrated design process to uncover performance and cost synergies. Instead, the industry is more speculative in nature, with a short-term focus, typically offering a small cross-section of home or unit models with various levels of finishes or energy-efficiency add-ons as a secondary consideration. The industry is therefore challenged to not only carry out costing studies to articulate the costs and benefits of green technologies, but also to subsequently "market" these green technologies to new home purchasers.

Focusing on the purchaser's perspective primarily means taking a narrower view of the possible range of benefits ascribed to any green technology; i.e., we are only interested in "green" [2]technologies that generate recoverable benefits to the investor and not the full range of benefits — some of which may benefit society as a whole. This focus limits the tool's application primarily to energy and water saving technologies, as it is likely that these technologies will provide a direct monetary benefit to the private investor (see Section 4 for actual technology case studies).

The LCC tool is structured as a set of linked worksheets. The first worksheet, "LCC assumptions and results", functions as both an input interface for the tool and a summary of the numeric results of the life cycle cost calculation (e.g., net present value, simple payback period and return on investment) for up to three investment scenarios. The three "results calculator" worksheets relate to each scenario case and show the annual cash

[2] Greening or green technologies has come to mean different things to different people. For this project where discernable monetary benefits are the only benefits of interest greening is interpreted as employing greater energy efficiency or water saving technologies.

flows by cost element, sum these for individual years on both a nominal and discounted basis, and calculate the life cycle cost results for the investment scenario over the expected life – up to 60 years.

Below is a list of the actual investment criteria and cost elements considered within the LCC Calculator tool.

- Total installed capital cost (net of rebates and subsidies).
- Initial investment amount.
- Capital financed (total capital cost - initial investment).
- The service life over which the investment is to be assessed (between 1 and 60 years).
- The discount/hurdle rate to be used for determining the net present value of an investment.
- Annual energy cost or savings broken down by fuel type.
- Annual maintenance costs.
- Annual financing costs (with side bar financing calculator requiring the user to input the financing interest rate and amortization period for the loan).
- Other annual costs or benefits (a catch-all line to include other annual savings or costs (e.g., water use charge savings in the case of a water saving technology).
- Periodic replacement costs and salvage values over the service life.

The tool also contains a number of default values for general and energy price inflation (by fuel type) to aid the LCC tool user. The various cells of the Excel© spreadsheet are also colour-coded to indicate values to be entered by the user, the values calculated by the tool and default values contained in the tool which may be changed by the user. A text box at the bottom of the sheet briefly explains what a "discount rate" is and how it may be selected for various types of clients (e.g., a home owner may use a mortgage rate while a developer may wish to use a hurdle rate more in keeping with his or her investment strategy).

The financial measures (results) calculated by the tool include the following:

- the net present value of the investment over the service life (study period) as well as at periodic points equalling one-third and two-thirds of the investment service life;
- a simple pay-back period result for the <u>initial cash investment</u> (including any financing costs) as well as for the <u>total project cost</u> (which excludes any annual financing costs) – see users' guide for a discussion of these two payback measures; and
- the return on investment (ROI) or internal rate of return (IRR) for the investment.

Finally, the tool is structured such that it allows up to three investment scenarios to be considered side by side. This is useful when the tool user wants to compare a more conventional technology with a green technology, or conduct a sensitivity analysis around various variables pertinent to a green technology investment (e.g., changes in capital cost, avoided cost/price of conventional energy sources, or including and excluding financing costs, etc.).

The simplicity of the tool lies in the fact that all the analysis inputs and results are reported on a single worksheet (see Figure 1 below), which is easily viewed and printed. All the data input descriptor cells are fully documented in comment boxes attached to the cells.

The "Results Calculator" worksheets take the cost and savings inputs entered on the first sheet and populate and calculate the annual LCC results over the investment period based on the input values for each scenario entered. Tool users can see the detailed annual nominal and discounted cash flows based on their input variables. These spreadsheets provide transparency concerning the inputs and results, but it is not necessary to view these additional worksheets to use the tool.

The users' guide documents each field to be completed by the tool user, provides sources for various data elements, and describes each of the results in simple terms to make LCC more accessible to the building community. The users' guide also contains an example LCC calculation, complete with the various inputs and results indicated via a screen capture of the tool.

Figure 1 LCC Calculator Main User Interface Worksheet (Example)

CMHC Life Cycle Cost Calculator			
developed by the Athena Institute	yellow "shaded" cells to be completed by the tool user		
	violet "shaded" cells are calculated by model		
	orange "shaded" cells represent default values, changable by user		
COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	Traditional inverted roof	Extensive green roof	incremental analysis
Date &Time	31/01/06 10:18	31/01/06 10:18	31/01/06 10:18
Completed by:	Jamie Meil	Jamie Meil	Jamie Meil
Company	Athena Institute	Athena Institute	Athena Institute
Contact phone number	613.722.8075	613.722.8076	613.722.8077
Contact email	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca
Study Period in years	40	40	40
Applicable discount (hurdle) rate (%)	8	8	8
General price inflation factor (%)	2.5	2.5	2.5
Thermal fuel energy price inflation factor (%)	3.5	3.5	3.5
Electricity price inflation factor (%)	5	5	5
INVESTMENT DATA			
Investment Name (description)	Traditional inverted roof	Extensive green roof	incremental analysis
Total installed capital cost	$ 38,950	$ 72,380	$ 33,430
Initial cash investment amount	$ 38,950	$ 72,380	$ 33,430
Capital portion financed	$ -	$ -	$ -
financing annual interest rate (%)	0.00%	0.00%	0.00%
financing (amortization) period in yrs	$ -	$ -	$ -
Annual Financing costs	$0	$0	$0
Annual electricity energy savings or (cost)	$ -	$ 163	$ 163
Annual thermal fuel energy savings or (cost)	$ -	$ -	
Annual maintenance (costs) or savings	$ (390)	$ (202)	$ 188
Other annual (costs) or savings	$ -	$ -	$ -
Replacement interval in years	22	40	40
Periodic Replacement cost	$ 31,160	$ -	
Periodic Salvage value	$ -	$ -	$ -
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%	at a discount rate of 8%	at a discount rate of 8%
NPV for study period (yrs)	40 $ (54,738)	40 $ (71,823)	40 $ (26,503)
NPV at year (one-third of study period)	13 $ (42,534)	13 $ (72,487)	13 $ (29,953)
NPV at year (two-thirds of study period)	26 $ (54,218)	26 $ (72,215)	26 $ (27,864)
Simple Payback Period on initial **cash** (yrs)	Payback > study period	Payback > study period	39.9
Simple Payback Period on **total** project (yrs)	Payback > study period	Payback > study period	39.9
Internal Rate of Return on Investment (%)	-14.3%	-6.8%	0.0%

3 Green Technology Selection

3.1 Introduction

This section briefly describes the process by which the green technologies were first identified and eventually selected for the purpose of illustrating the use of the life cycle cost tool.

3.2 Identifying Green Technologies Methodology

When considering green technologies for LCC assessment it was paramount that the technologies demonstrate readily identifiable and tangible benefits. In addition, the technology itself needed to be definable as a "bolt on" technology (e.g., installation of higher efficiency windows or furnace, etc) rather than a greening practice (e.g., using an integrated design process or purchasing green energy). In order to develop a possible list of technologies, we first reviewed a number of North American green building rating systems to identify the various green technology themes advocated by these systems. The green building rating systems reviewed included the following:

- Built Green Alberta;
- National Association of Home Builders Green Home Guidelines;
- LEED for Homes (draft version);
- LEED Canada v1.0;
- Green Globes;
- Natural Resources Canada's Energuide for Houses;
- iiSBE's GBTool (Green Building) 2005 version;
- RETScreen International's renewables technology list; and
- NRCan's Energy Star for New Homes technical specification (pilot version).

These green technology themes were then categorized by effect type – energy use, water conservation, materials, indoor environmental quality, site and other effects. Figure 3.1 below summarizes the identified green themes by category for each of the rating systems reviewed. The thrust of this exercise was to gain a better understanding of the various green themes and the frequency of their occurrence across the various rating systems, thereby enabling us to identify a set of "bolt-on technologies" that addresses the major theme areas.

To this end, the various themes were further distilled down to a list of specific technical upgrades by theme category (Figure 2). Both the themes identified by the various rating systems and the specific technical upgrade listings were then circulated to the project's Steering Committee for input, discussion and eventual selection for LCC demonstration purposes. A set of 14 technologies was finally selected for illustrative LCC purposes; one of these applied to both multi-unit residential and single family housing, while the others were applicable to one type or the other. A complete list of selected technologies by housing type application is provided in Figure 4.

Figure 2 Green Theme Summary by Category and Rating System

	System Improvement bolded items indicate "bolt on" attribute with a definable payback	Built Green Alberta	NAHB Green Home	LEED for Homes	LEED Canada 1.0	Green Globes	Energuide for Houses	Gbtool 2005	RETSCREEN	Energy Star for New Homes
Energy Use	minimize overall energy use	X	X	X	X	X	X	X		X
	high efficiency envelope	X	X	X			X			X
	innovative envelope	X	X							
	efficient windows	X	X	X			X		X	X
	efficient HVAC systems	X	X	X			X	X		X
	efficient water heater	X	X	X			X		X	X
	high efficiency lighting	X	X	X						X
	on site renewable energy	X	X	X	X	X		X	X	
	purchase green power		X		X	X		X		
	efficient appliances	X	X	X						X
	integrated site specific design		X			X		X		
	verification / testing		X	X	X			X		
water conservation	**high efficiency fixtures / systems**	X	X	X	X	X	X	X		
	water conserving appliances	X	X			X				
	drought resistant landscaping	X	X	X	X	X		X		
	collect rain water	X	X	X	X	X		X		
	grey water use		X	X	X	X		X		
	water metering					X		X		
Materials	use LCA		X			X		X		
	recycled content	X	X	X	X	X		X		
	sustainable materials	X	X	X	X	X		X		
	salvaged materials		X		X	X		X		
	minimization of materials	X	X	X						
	modular / panelized construction		X					X		
	recycling program / composting	X	X		X	X		X		
	construction waste reduction	X	X	X	X	X		X		
	durable materials	X	X	X	X			X		
	short travel distances	X	X	X	X	X		X		

Figure 2 continued

	System Improvement bolded items indicate "bolt on" attribute with a definable payback	Built Green Alberta	NAHB Green Home	LEED for Homes	LEED Canada 1.0	Green Globes	Energuide for Houses	Gbtool 2005	RETSCREEN	Energy Star for New Homes
IEQ	benign materials	X	X		X	X		X		
	controllability				X			X		
	views				X			X		
	maximize daylighting				X	X		X		
	consideration of sound					X		X		
Site	protection of natural features	X	X	X		X		X		
	smart growth		X	X	X	X		X		
	Shared driveways		X							
	Storm water management		X		X	X		X		
Other	**Smaller home**		X	X		X				
	homeowner education		X				X			
	Green Roofs				X	X		X		
	detailed plans		X			X				
	CFC / HCFC reduction				X	X				

Figure 3 Specific Technical Upgrades by Theme Category

	System improvement ("bolt on" items with definable payback)	Specific technical upgrade
Energy Use	high efficiency envelope	Higher insulation values
		High degree of air sealing
		reduced glazing
	innovative envelope	ICF's SIP's
		exterior insulation
	efficient windows	thermally efficient frames
		low e / argon
		insulating spacer
		triple glazing
	efficient HVAC systems	gound source systems
		high efficiency furnaces/AC
		radiant floor heating
		efficient duct work
		solar (passive solar) air heating
		natural ventilation
		heat pumps
	efficient water heating	insulated water lines
		solar water heating
		manifold plumbing
		drain water heat recovery
	high efficiency lighting	efficient fixtures
		efficient bulbs
		tubular skylights
	on site renewable energy	photovoltaics, wind
	efficient appliances	washer, dryer, dishwasher
		stove, refridgerator
water conservation	high efficiency fixtures / systems	dual flush toilets, waterless urinals
		aerating taps
		low flow showers
		shower shut off valves
	water conserving appliances	washing machine, dishwasher
	rain water harvesting	for landscaping
		for use in fixtures
	grey water use	grey water use
	water metering	water metering
Materials	salvaged materials	salvaged materials
	minimization of materials	OVE approach
		elimination of finish materials
	modular / panelized construction	modular / panelized construction
	construction waste reduction	construction waste reduction
	durable materials	building envelope
		heating systems
		interior finishes
Oth er	Smaller home	Smaller home
	green roofs	green roofs

Figure 4 Final Green Technologies for LCC Demonstration by Housing Type

	System improvement ("bolt on" items with definable payback to consumer)	Specific Technical Upgrade by Housing Type Application	homes	murbs
Energy Use	high efficiency envelope			
		High degree of air sealing	X	
		reduced window to wall ratio		X
	innovative envelope			
		greater exterior insulation	X	
	efficient windows			
		low e / argon / spacer / frame type		X
	efficient HVAC systems			
		high efficiency furnaces	X	
		condensing boilers (MURBS)		X
		HRV's - unit HVAC only	X	X
	efficient water heating			
		solar water heating	X	
		heat capture from waste water		X
	on site renewable energy			
		photovoltaic		X
water	high efficiency fixtures / systems			
		dual flush toilets		X
	rain water harvesting			
		for landscaping	X	
Oth				
	green roofs	green roofs		X
	TOTAL by Housing Type		6	8

4 Green Technology Case Studies

For each of the selected technologies we developed illustrative life cycle cost data and investment criteria. Each case study shows the investment criteria, cost and benefit data as entered into, and the results generated by, the LCC Calculator tool for the green technology under consideration. The objective of the various case studies was not to produce a definitive LCC result, but rather to give an indication of the data necessary to support an LCC analysis and how this data is entered and used within the LCC tool to arrive at a result. Each of the following sections is devoted to a case study of one of the selected green technologies indicated in Figure 3 above. To further illustrate how the cost and benefit information pertaining to each technology was entered into the LCC Calculator, Appendix B provides screen captures of the LCC Calculator's summary input and results sheet corresponding to each case study technology assessed.

In the process of completing the investment analysis, a number of overarching assumptions were necessary to frame the analysis. These assumptions are listed below and relate to two locations: Ottawa and Vancouver.

<u>Common Assumptions</u>:

1. Electricity, natural gas and potable water prices used in the investment analysis were obtained from local utilities, natural gas suppliers and municipalities (Ottawa and Vancouver). These rates are current as of time of analysis (2006) and are as follows: for Ottawa - electricity \$0.0909/kWh, natural gas \$0.483/m^3 and water \$0.692/m^3; for Vancouver - electricity \$0.0605/kWh, natural gas \$0.487/m^3 and water \$0.52/m^3.
2. General Price inflation: to average 2.5% over the investment period.
3. Electricity Price Inflation: to average 3% over the investment period.
4. Thermal Fuel Price Inflation: to average 9% over the investment period.
5. Discount (Hurdle) Rate: assumed to be 8% for single family homes (approximate mortgage rate) and 15% for MURBS (owner return on investment requirement).
6. Financing costs excluded from analysis.

<u>Single Family Home Assumptions</u>:

7. HOT2000 software, with weather data and utility rates for Ottawa or Vancouver, was used to determine energy related benefits.
8. Base house is 2-storey, 2000 ft^2 total, 15% windows (mostly front and back), sloped roof, natural gas heating, south front orientation, suburban/forest terrain.
9. The typical house employs 2x6 wood stud walls with glass fibre batt insulation.
10. The house employs PVC cladding.
11. The attic contains R40 of insulation.

<u>Multi-Unit Residential Building (MURB) Assumptions</u>:

12. EQuest energy modelling software (version 3.55), with weather data and utility rates for Ottawa or Vancouver, was used to determine energy related benefits.
13. Base building is 8-storey (+1 below grade), 8 units/floor, 72,000 sq. ft.

14. Base window to wall ratio is 60%. Base window type is double clear, 1/8", 1/4" air, aluminium with break frame.
15. Construction types, materials are all default selections within EQuest software. Specifically, building systems include the following systems.
    a. Walls are metal framed (2x6) with glass fibre insulation, exterior sheathing, glass and spandrel cladding.
    b. Roof is metal framed, built up roof, with 37 mm of polyurethane insulation and extra layer of R38 batt insulation.

4.1 Single Family Homes

4.1.1 Case Study No. 1: Achieve High Degree of Building Envelope Air Sealing

Background and Technology Description

One purpose of the building envelope is to resist the movement of air, either from the interior to the exterior of a building or vice versa. Uncontrolled air leakage will result in increased energy use (and the associated environmental effect[3]), as well as occupant comfort issues, and potential condensation within a wall assembly (with resulting material degradation and mould growth).

Typical house design involves the selection of a material or system that acts as an air barrier. Many homes rely on polyethylene sheeting for this purpose, although gypsum board, spun-bonded polyethylene, and wood sheeting can also serve as an element in an air barrier system. Each of these materials has permeability characteristics that make it suitable, as a material, for an air barriers, and there is little difference in resistance to air passage within the field of these materials.

Another important consideration in developing a functional air barrier system, however, is the connection of the various elements. For home construction, there is often some difficulty in maintaining air tightness across intermediate floors, at wall penetrations (such as electrical outlets or vents) or at connections between wall elements (ceilings, floors, windows). Typically, it is in these connections that better resistance to air leakage can be achieved, often through improved detailing and construction practices. The knowledge and capability needed to achieve large improvements in air tightness of houses is readily available, but it is not often incorporated in buildings due to the increased time necessary for construction detailing, as well as the difficulty in measuring air tightness; these factors result in a lack of incentive for a builder to focus on this issue. In some cases, builders do employ exterior spun-bonded polyolefin sheets (such as Tyvek™), marketed as air barriers, but these systems are often poorly detailed, resulting

---

[3] For instance, reduced carbon dioxide emissions. The application of this technology has the potential to save $750 per annum or 1550 cubic meters of natural gas (at $0.483/m^3 of natural gas). Natural gas has a higher heating value of 38.03 MJ/m^3 and its combustion releases 49.7g of CO_2 per MJ. Therefore, the potential CO_2 emission savings per annum would be in the order of 77 kg of CO2 or 2.3 tonnes of CO_2 over the 30 year investment life.

in their inability to function properly. . Spun bonded polyolefin based air barrier systems can function well (as air barriers), but their success is often dependent on proper installation at important (and difficult) details.

Assumptions and Costs

For the purposes of this case study, we have assumed that increased air tightness will be achieved through the use of an exterior spun-bonded polyolefin sheet (such as Tyvek™), and that this system will be properly detailed at critical connections and penetrations.

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 30 years (it is acknowledged that the air barrier may last longer than this period, but we believe that a 30-year period represents a very long timeframe with respect to economic analysis).
- The "average" air tightness for a "standard" house was 4.55 ACH @ 50 Pa. This is the baseline air leakage characteristic option given in the HOT2000 model.
- Air sealing: upgrade was selected as 1.55 ACH@ 50 Pa. This is the best air leakage characteristic option (defined as "energy tight") given in the HOT2000 model.
- To develop the differential costs, the base building was assumed to incorporate perforated asphalt impregnated paper (tar paper), as a drainage layer.
- The house is located in Ottawa.

The cost variables listed in the Table below were entered into the "LCC Calculator". The various sources for the information to frame the analysis are listed in the notes accompanying the Table.

Cost Variables

	Upgraded Exterior Air Barrier
Incremental capital cost	$550
Expected life	30 yrs +
Annual maintenance cost	$0
Annual natural gas energy cost savings	$750

LCC Results and Discussion

The LCC Calculator results for the improved exterior air barrier are summarized in the Table below (see Appendix B, Case Study No. 1, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The expected savings in natural gas use in the first year surpasses the additional incremental capital cost of the upgraded exterior air barrier. Consequently, the investment achieved a considerable positive net present value over the thirty year study period, a short payback period of less than a year, and a return on investment of greater than 150%. By all measures, the investment is worthy of the initial investment.

LCC Results for Improved Single Family Home Air Sealing

	LCC Results
Net present value at yr 30	$25,488
Payback period	0.7 years
Internal rate of return	150%

4.1.2 Case Study No. 2: Increased Exterior Wall Insulation

Background and Technology Description

One purpose of the building envelope is to resist the transfer of heat, either from the interior to the exterior of a building or vice versa (depending on the exterior air temperature). Levels of insulation within Canadian housing are typically defined by the building code in the area of construction, even though the building code is intended as a minimum standard.

Commercially available wall systems and components can be employed to increase the thermal resistance of wall assemblies. Increased thermal resistance will result in decreased energy use (cooling and heating), and a corresponding decrease in environmental effects associated with energy production.

Potential methods of increasing the thermal resistance of wall assemblies include the use of thicker wall assemblies with more insulation, the use of double stud wall assemblies (with increased insulation), or the use of a continuous layer of insulation on the exterior of a wall assembly. We believe that these methods are rarely employed in conventional housing due to a lack of demand, possibly caused by relatively low energy prices coupled with weak buyer knowledge concerning the benefits of increased insulation.

Assumptions and Costs

For the purposes of this case study, we have analyzed the effects of increased thermal resistance by providing exterior R8 insulation on a conventional insulated residential wall (2x6, with 150mm of fibreglass batt in cavity).

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 30 years (it is acknowledged that increased insulation levels are likely to last longer than this period, but we believe that a thirty year period represents a very long time frame with respect to economic analysis).
- Exterior insulation: 50 mm of expanded polystyrene.
- The house is located in Ottawa.

The cost variables listed in the Table below were entered into the "LCC Calculator". The various sources for the information to frame the analysis are listed in the notes accompanying the Table.

Cost Variables

	R8 Exterior Insulation
Incremental capital cost	$8500
Expected life	30 yrs +
Annual maintenance cost	$0
Annual natural gas energy cost savings	$400

LCC Results and Discussion

The LCC Calculator results for the upgraded level of insulation are summarized in the Table below (see Appendix B, Case Study No. 2, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment achieved both a positive net present value and return on investment greater than the acceptable minimum hurdle rate. The payback period is about 12 years and is rather long by investment standards; however, this rather passive technology is not likely to fail and will last the life of the house, so the associated risk of this investment is considered low relative to other possible investment vehicles.

LCC Results for Improved Single Family Home Exterior Wall Insulation

	LCC Results
Net present value at yr 30	$5,387
Payback period	11.7 years
Internal rate of return	11.6%

4.1.3 Case Study No. 3: Install High Efficiency Furnace with Heat Recovery Ventilator (HRV)[4]

Background and Technology Description

In Canada, all houses require a source of heat to make up heat losses to the environment. The most common source of heat employed in residential housing in Canada is the fuel-fired furnace. Fuel-fired furnaces affect the environment as a result of the products of combustion and the operation of the fan or pump required to distribute the heat; both of these factors result in the production of greenhouse gases.

When relying on fuel-fired residential heating systems, developers typically employ mid-efficiency furnaces. These systems burn indoor air for heat, so combustion air needs to be provided (typically through a vent to the outdoors). There are also code requirements for ventilation, which are typically provided through exhaust only vents.

Higher efficiency furnaces are readily available, and are not uncommonly used in Canada. Further, more efficient forms of ventilation are also available. Heat recovery ventilators (HRV's) capture waste heat from combustion exhaust air and transfer it to the

[4] Note that this case study combines two of the single family home technologies selected for analysis by the Project Steering Committee – high efficiency furnaces and HRVs

incoming ventilation air, thus offsetting some of the effects of conditioning ventilation air.

Assumptions and Costs

For the purposes of this study, we have compared the operational benefits of a house with a conventional mid-efficiency gas furnace and an exhaust only ventilation unit to a similar house with a high efficiency gas furnace and HRV.

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 20 years. This is the approximate amount of time that the furnace will remain operational.
- The base case furnace efficiency was 78%.
- The upgraded furnace efficiency was 96%.
- The efficiency of the HRV in the upgraded case was 65%.
- Maintenance costs represent the increase in maintenance from the base case to the upgraded scenario. It is expected that the increased complexity between the upgraded and conventional systems will result in increased maintenance. We have assumed that the average additional maintenance cost will not be the result of increased regular maintenance, but rather a one-time component replacement amounting to 20% of the total incremental cost.
- The house is located in Ottawa.

The cost variables listed in the Table below were entered into the "LCC Calculator". The various sources for the information to frame the analysis are listed in the notes accompanying the Table.

Cost Variables

	Upgraded Heat Delivery
Incremental capital cost	$2000
Expected life	20 yrs
Annual maintenance cost	$10
Annual energy cost savings	$500

Note: Annual maintenance costs are distributed over entire life of systems.

LCC Results and Discussion

The LCC Calculator results for the upgraded high efficiency furnace in combination with installing an HRV are summarized in the Table below (see Appendix B, Case Study No. 3, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment achieved both a healthy positive net present value and a return on investment that is much greater than the minimum acceptable hurdle rate. The payback period is also quite short at 1.8 years. Both high efficiency furnaces and HRVs are proven technologies and are very worthy energy efficiency upgrade investments.

LCC Results for Single Family Home High Efficiency Furnace + HRV

	LCC Results
Net present value at yr 20	$9,722
Payback period	1.8 years
Internal rate of return	62.2%

4.1.4 Case Study No. 4: Solar Hot Water Heating

Background and Technology Description

Solar hot water systems use the sun's energy to heat water, thus reducing or eliminating the need to use conventional fuel fired or electric hot water heaters. There are two types of solar hot water systems: direct systems, which use the sun to heat water directly; and indirect systems, which rely on a secondary fluid and a heat exchanger to capture the sun's energy. Direct systems are best suited for warmer climates, while indirect systems work better in colder climates, as there is no risk of freezing water. Solar hot water systems can also be either active (pump assisted) or passive (reliant on convective forces) systems. This section focuses on active indirect systems as it best applies to the Canadian climate.

An active solar water heater uses electrically powered pumps, valves and other equipment to help circulate anti-freeze through the system. There are five major components in active solar water heating systems:

- collectors to capture solar energy;
- a circulation system to move a fluid between the collectors and a storage tank;
- storage tank;
- backup heating system; and
- control system to regulate the overall system.

Water heating in Canada currently accounts for approximately 20% of residential energy use, representing about 15 megatonnes of CO_2 emissions per year for an average of two tonnes of CO_2 per water heater. Solar water heaters can make a significant contribution to CO_2 emission reduction as each installation reduces conventional energy use, with corresponding reductions in global warming contributions.

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- The size of the solar water heater was assumed to be a 1.3 MWH system with a 150 litre tank.
- It is acknowledged that solar water heating systems are essentially maintenance free. However, we have assumed that a one-time component replacement will be required, amounting to approximately 10% of the total cost. This cost is distributed over the life of the assembly in the table below.
- The house is located in Vancouver.

The cost variables listed in the Table below were entered into the “LCC Calculator”.

Cost Variables

	Solar Hot Water
Incremental capital cost	$4500
Expected life	25 yrs
Annual maintenance cost	$20
Annual energy cost savings	$100

Note: Capital costs were developed using commercial costing (RSMeans) packages. Energy savings were developed using manufacturers’ data and the RETScreen software.

LCC Results and Discussion

The LCC Calculator results for the solar hot water system are summarized in the Table below (see Appendix B, Case Study No. 4, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment generated a negative net present value and an internal rate of return only about half that of the desired hurdle rate of 8%. Further, the simple payback period for the solar hot water system approaches four-fifths of the technology’s expected service life; as a result, any unforeseen costs (e.g., additional circulation pump breakdowns) would consume even the slight return the technology is currently generating. This technology as a potential investment appears to be marginal at best.

LCC Results for Single Family Home Solar Hot Water Heating System

	LCC Results
Net present value at yr 25	($2,033)
Payback period	19.3 years
Internal rate of return	3.7%

4.1.5 Case Study No. 5: Rainwater Harvesting

Background and Technology Description

Buildings typically utilize potable water for a number of purposes where perfectly clean water may not be necessary, such as irrigation or for lavatories. There is the potential to capture storm water and utilize it to offset potable water use.

Stormwater collection (or rainwater harvesting) can be defined as the collection and storage of rainwater in some natural or artificial container either for immediate use or for use at some later time. Rainwater is usually collected or harvested from rooftops and used for a variety of functions, including irrigation, grey water and, after purification, potable water. The most common of these uses is irrigation, where water is collected from a rooftop and distributed to grade level landscaped areas. Some systems utilize cisterns that are either internal or external to a building, so that rainwater delivery to landscaped areas can be controlled. The simplest, and most common means to store water, is through the use of a rain barrel, positioned to capture rooftop rainwater and to rely on gravity for distribution from the barrel.

The use of reclaimed water results in the following environmental benefits.

- Potable water use reduction: the creation and use of potable water results in treatment chemical use (chlorine, alum, fluoride), lowering of natural waterways or aquifers (depending on the source of water), and small amounts of energy use (for pumping). The use of site water in lieu of off-site treated potable water will reduce these effects.
- Most buildings replace pervious ground surfaces with some impervious roof or grade level surfaces. These impervious surfaces result in an increase in storm water surges (as water is directed to sewers or ditches). The use of on-site storm water for other purposes can reduce the volume of storm water surge, and can accordingly reduce the associated environmental effects. Note that storm water use as described in this section will do little to reduce the peak storm water surge: peak storm water flows are generally believed to be more important than volume flows with respect to environmental consequences.
- The building is located in Vancouver.

Reliance on rainwater collected from a roof does present a number of risks, including the lack of reliable water supply and the risk of contaminants.

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 20 years. This represents the approximate serviceable life of the rain barrel.
- Annual water savings were developed using a general rule of thumb (from the manufacturer) that outside water represents about 50% of summer water use. We also assumed that 20% of outdoor water use would be offset by rain barrels.
- The house is located in Ottawa.

The cost variables listed in the Table below were entered into the “LCC Calculator”.

Cost Variables

	Rain Barrels
Incremental capital cost	$100
Expected life	20 yrs
Annual maintenance cost	$0
Annual cost savings	$20

Note: Capital costs were developed from consultation with manufacturers, and assume a city rebate of 50%.

LCC Results and Discussion

The LCC Calculator results for the rainwater system are summarized in the Table below (see Appendix B, Case Study No. 5, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment generated a positive net present value and an internal rate of return well above the minimum acceptable hurdle rate. Further, the simple payback period for the rainwater collection system is less than five years and poses little risk. The investment scenario was also analysed with no 50% capital cost rebate and, as predicted, the return on investment (ROI) and simple payback results were about half of the base analysis with the 50% rebate. Both investment scenarios surpassed the required hurdle rate and with the small amount of capital at risk, the investment is acceptable.

LCC Results for Single Family Home Rainwater Collection System

	LCC Results (with 50% rebate)	LCC Results (with no rebate)
Net present value at yr 20	$142	$42
Payback period	4.7 years	8.8 yrs
Internal rate of return	22.4%	10.4%

4.2 Multi-Unit Residential Buildings (MURBs)

4.2.1 Case Study No. 6: Reduced Window to Wall Ratio

Background and Technology Description

High rise buildings, including MURBS, are more often increasing the relative area of windows to opaque walls. The likely cause of this trend is public demand. However, the general public is not aware that windows are fairly poor thermal insulators when compared to opaque walls. Accordingly, increasing the relative area of windows to opaque walls will result in increased energy used to condition (heat or cool) interior spaces. Increasing windows also increases the likelihood of problematic glare, thermal comfort concerns, and privacy issues.

Assumptions and Costs

In order to prepare this LCC analysis, a number of assumptions were necessary; they are listed below.

- Investment period: 25 years.
- Base case building and upgraded design utilize 60% and 30% (respectively) window to opaque wall ratio.
- Windows and contain identical glazing: double glazed, low-e coating, argon fill.
- Windows selected incorporate thermally broken aluminium frames.
- Costing and energy savings effects calculated for the entire building.
- It was assumed that there would be no significant difference between the two scenarios in maintenance costs.
- The building is located in Vancouver.

The cost variables for this scenario are listed in the Table below.

Cost Variables

	Decreased Window / Wall Ratio
Incremental capital cost	-$80,000
Expected life	25 yrs
Annual maintenance cost	$0
Annual energy cost savings	$4000

Note: Capital costs are reduced through the implementation of this scenario.

LCC Results and Discussion

This particular technical building design change does not immediately lend itself to an LCC analysis. Keeping in mind that LCC's primary evaluation mode is determining whether the higher initial cost of an investment is justified by reductions in future costs, the reduction in the window to wall ratio actually incurs less initial capital cost and reduced annual operating energy costs. Hence, without any economic analysis, it is clear that this is a beneficial design goal.

4.2.2 Case Study No. 7: Upgraded Window System

Background and Technology Description

High rise building developers often select window systems using criteria heavily weighted towards cost and aesthetics. Essentially, these systems are chosen to reflect public demands. Typically, MURB buildings that utilize punched window systems (as opposed to curtain wall) incorporate thermally broken aluminium framed windows, with fairly conventional double glazing.

From a heat transfer perspective, there are other available window systems that show improved performance. Potential improvements to reduce heat transfer in a window include the following:

- selection of an insulating frame (wood, PVC, glass fibre);
- the use of triple glazing;
- the use of a low-e coating on the glazing, and an inert gas (such as argon) fill; and
- the use of an insulating spacer (instead of aluminium or steel) for the glazing.

The environmental benefits of selecting more thermally efficient window systems are related entirely to energy use reductions (heating and cooling).

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 25 years. This represents the approximate serviceable life of the window systems.
- Base case building windows assumed to have thermally broken aluminium frames with conventional double glazing, clear glass, with air filled void.

- Upgraded window systems assumed to have reinforced PVC frames, double glazing with a low-e coating (e3=0.2), clear glass, with argon filled void.
- Costing and energy savings effects calculated for the entire building.
- The building is located in Ottawa.

The cost variables listed in the Table below were entered into the "LCC Calculator".

Cost Variables

	Upgraded Window System
Incremental capital cost	$25,000
Expected life	25 yrs
Annual maintenance cost	$100
Annual electricity cost savings	$1,600
Annual natural gas cost savings	$8,400

Note: Maintenance costs represent increased cost of replacement glazing units in the upgraded scenario.

LCC Results and Discussion

The LCC Calculator results for the upgraded window system are summarized in the Table below (see Appendix B, Case Study No. 7, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment generated a positive net present value and an internal rate of return well above the minimum acceptable hurdle rate. Further, the simple payback period for the upgraded window system is 2.2 years. Based on these financial measures, the upgraded window system is a sound investment.

LCC Results for MURB – Upgraded Window System

	LCC Results
Net present value at yr 25	$99,713
Payback period	2.2 years
Internal rate of return	51.0%

4.2.3 Case Study No. 8: Install Condensing Boiler

Background and Technology Description

A condensing boiler is a high efficiency modern boiler that incorporates an extra heat exchanger so that the hot exhaust gases lose much of their energy to pre-heat the water in the boiler system. When the boiler is working at peak efficiency, the water vapour produced in the combustion process condenses back into liquid form, releasing the latent heat of vaporization. A side effect is that this water, known as condensate, which is usually acidic, has to be piped away to a drain or soak-away. Condensing gas furnaces are generally 10-15% more efficient than conventional units.

The environmental benefits of selecting more efficient boiler systems are related entirely to energy use reductions. Production of the majority of electricity in Ontario is provided through coal and gas fired generation, nuclear power, and hydroelectric power. Each of these methods of energy production results in a myriad of environmental effects: every thousand kilowatt hours of electrical energy use in Ontario results in approximately 360 kg of equivalent CO_2, an important contributor to global warming. The use of clean alternative energy production methods reduces the environmental impact associated with energy production to near zero.

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 30 years. This represents the approximate serviceable life of a condensing boiler.
- Base boiler efficiency is 80%.
- Condensing boiler efficiency is 96%.
- Costing and energy saving effects were calculated for the entire building.
- Maintenance costs represent the increase in maintenance from the base case to the upgraded scenario. It is expected that the increased complexity of the upgraded system will result in increased maintenance. We have assumed that the average additional maintenance cost will be approximately 10% of the total incremental cost, distributed over the life of the assembly.
- The building is located in Ottawa.

The cost variables listed in the Table below were entered into the "LCC Calculator".

Cost Variables

	Condensing Boiler
Incremental capital cost	$25,000
Expected life	30 yrs
Annual maintenance cost	$100
Annual natural gas energy cost savings	$6,000

LCC Results and Discussion

The LCC Calculator results for the upgrade to a condensing boiler system are summarized in the Table below (see Appendix B, Case Study No. 8, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment generated a positive net present value and an internal rate of return twice that of the minimum acceptable hurdle rate. Further, the simple payback period for the condensing boiler system is 3.5 years. Based on these financial measures, the upgrade to a condensing boiler system is a sound investment.

LCC Results for MURB – Upgrade to Condensing Boiler System

	LCC Results
Net present value at yr 30	$61,364
Payback period	3.5 years
Internal rate of return	34.8%

4.2.4 Case Study No. 9: Install Heat Recovery Ventilators within MURB units

Background and Technology Description

In Canada, all units within MURBS require a source of heat to resist winter heat loss. The most common sources of heat employed in MURBS in Canada are fuel-fired furnaces and boilers. Fuel-fired systems affect the environment as a result of the products of combustion and the operation of the fan or pump required to distribute the heat; both of these factors result in the production of greenhouse gases.

For ventilation air, MURBs in Canada typically employ ducted systems or rely on ventilation from the corridor. The exhaust air within a MURB unit is often vented directly to the outdoors.

There is the potential for each MURB unit to include a heat recovery ventilators (HRV) that captures waste heat from exhaust air and transfers it to ventilation air, thus offsetting some of the effects of conditioning ventilation air. In addition, this system does not rely on ventilation from corridor areas, a method which has historically been problematic with respect to control of sound and odours.

Assumptions and Costs

For the purposes of this study, we have compared the operational benefits of a MURB unit using conventional ventilation to a unit with an HRV.

In order to prepare this LCC analysis, a number of assumptions were necessary; they are listed below.

- Investment period: 20 years. This is the approximate amount of time that an HRV will remain operational.
- The efficiency of the HRV in the upgraded case is 65%.
- The energy modelling software (EQUEST) did not allow each unit to incorporate an HRV. Accordingly, the cost benefits developed below were based on a more contrived modelling in HOT2000 for a home modelled as separate suite units with shared walls, and assuming a ventilation rate of 75 L/s (reference Ontario Building Code)
- The building is in Ottawa.

The cost variables listed in the Table below were entered into the “LCC Calculator”.

Cost Variables

	Install Unit HRV
Incremental capital cost per unit	$1000
Expected life	20 yrs
Annual maintenance cost	$10
Annual electricity cost savings	$100
Annual natural gas cost savings	$300

Note: HRV installed capital cost from RS Means Price Book. Annual maintenance costs are estimated at 10% of capital costs annualised over the service life of the system. Calculated savings are based on HOT2000 simulation.

LCC Results and Discussion

The LCC Calculator results for installing HRVs in individual MURB suites are summarized in the Table below (see Appendix B, Case Study No. 9, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The investment generated a positive net present value and an internal rate of return well above that of the minimum stipulated hurdle rate. Further, the simple payback period for the investment is 2.3 years. Based on the calculated costs and energy savings, the resulting financial measures indicate that the installation of HRVs in individual MURB suites is a sound investment. Although the energy savings estimates were arrived at in a less than straightforward manner, the results indicate that even if the energy savings were only half of those expected, the investment would still surpass the 15% hurdle rate by about a factor of two (see below and screen capture cited above).

LCC Results for MURB – Install HRV in a MURB suite

	LCC Results	LCC results at 50% energy savings
Net present value at yr 20	$3,274	$2,820
Payback period	2.3 years	4.3 years
Internal rate of return	49.7%	27.8%

4.2.5 Case Study No. 10: Heat Recovery from Waste Water

Background and Technology Description

A wastewater heat recovery system reclaims heat energy from hot water that is typically lost in the plumbing drainage system. This heat can be claimed either directly, through absorption into a cold water line, or indirectly, through the use of a heat pump and a wastewater storage tank. The direct method is the most popular method of heat recovery from wastewater, and is the focus of this section.

Direct heat recovery is typically achieved by using a heat exchanger. The incoming cold water runs through a coil of pipe wrapped around the wastewater drain. As warm water drains away, it transfers its heat through the pipe walls into the water going to the water heater. This gives the water heater less work to do, saving water heater energy. The actual amount of heat saved is dependent on the type and extent of water use, and the location of the heat exchanger. For example, frequent showers will increase efficiency of these systems, but baths will achieve almost no benefit.

Water heating in Canada currently accounts for approximately 20% of residential energy use, representing about 15 megatonnes of CO_2 emissions per year for an average of two tonnes of CO_2 per water heater. Preheating water entering a water heater will reduce the energy used (as well as the resulting environmental effects).

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 30 years. This represents the approximate serviceable life of a waste water heat recovery system.
- Data on energy savings and costing obtained from a system manufacturer (PowerPipe system).
- Energy savings were developed on the assumption of frequent use. Accordingly, this might be more applicable for a health area within a MURB, rather than the actual units.
- Costs are presented an a singular system basis.
- The building is located in Vancouver.

The cost variables listed in the Table below were entered into the "LCC Calculator".

Cost Variables

	Drain Water Heat Recovery
Incremental capital cost	$1000
Expected life	30 yrs
Annual maintenance cost	$0
Annual natural gas cost savings	$180

LCC Results and Discussion

The LCC Calculator results for incorporating a drain water heat recovery system are summarized in the Table below (see Appendix B, Case Study No. 10, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The base case investment generated a positive net present value and an internal rate of return about twice that of the minimum stipulated hurdle rate. The calculated simple payback period for the investment is 4.4 years, representing only about one-sixth of the system's expected service life. The above financial results are dependent on capturing the stated energy savings associated with frequent use.

In order to determine whether the investment is still viable under a more likely residential unit use pattern, a second investment scenario was conducted, based on only capturing 50% of the calculated energy savings in Scenario 1 ($180/2 = $90). This second case indicated a small positive net present value, an internal rate of return quite close to the minimum acceptable hurdle rate, and a simple payback period of 7.5 years. Therefore, the investment shows a high degree of sensitivity to the attained energy cost savings. Although other green technology investments may provide a greater return, the wastewater heat recovery system is neither particularly capital intensive nor prone to mechanical failure, and is likely to generate a return in long-term use.

LCC Results for MURB – Install Drain Water Heat Recovery System

	LCC Results "frequent use"	LCC results at 50% energy savings
Net present value at yr 30	$1,615	$307
Payback period	4.4years	7.5 years
Internal rate of return	28.5%	17.9%

4.2.6 Case Study No. 11: Install Photovoltaic Panels

Background and Technology Description

Photovoltaic (PV) systems convert sunlight (solar energy) into electricity. Solar energy is composed of photons, which, when absorbed by a PV system, generate electricity.

Two general types of solar collectors currently available are flat plate and concentrator. Flat plate collectors consist of an array of PV panels that absorb the sun's energy directly. Concentrator collectors increase the intensity of sunlight with lenses.
PV modules are typically interconnected as arrays, using metal wire or mesh-like ribbons that are usually kept as short as possible. The interconnections between modules can be rigid or flexible, although flexible connections contend better with movement within the array caused by environmental forces such as thermal expansion.

Photovoltaic arrays have to be mounted on some sort of stable, durable structure that can support the array and withstand wind, rain, hail, and other adverse conditions. The mounting structure can either be stationary or it can track the sun. It is common to support PV arrays on roofs, walls, or stand-alone structures.

As mentioned previously, production of the majority of electricity in Ontario is provided through coal and gas fired generation, nuclear power, and hydroelectric power. Each of these methods of energy production results in a myriad of environmental effects: every thousand kilowatt hours of electrical energy use in Ontario results in approximately 360 kg of equivalent CO_2, an important contributor to global warming. The use of clean alternative energy production methods, such as PV, reduces the environmental impact associated with energy production to near zero.

Assumptions and Costs

For the purposes of this study, we have assumed that a MURB will employ a plate type collector mounted on a roof, with a total maximum output of 1000W of power.

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 25 years. This is the approximate amount of time that a PV panel will remain operational.
- Average generation rates obtained from CMHC publications. These publications relied upon the RETScreen software.
- System costs obtained from RS Means costing data.
- It is acknowledged that PV systems are essentially maintenance free. However, we have assumed that a one-time component replacement will be required, amounting to approximately 10% of the total cost. This cost is distributed over the life of the assembly in the table below.
- The building is located in Vancouver.

The cost variables listed in the Table below were entered into the "LCC Calculator". The various sources for the information to frame the analysis are listed in the notes accompanying the Table.

Cost Variables

	1000W PV panel
Incremental capital cost	$10,000
Expected life	25 yrs
Annual maintenance cost	$40
Annual electricity cost savings	$1000

Note: Energy cost savings based on purchased electricity reduction with no PV generated electricity being sold back to the BC electricity grid.

LCC Results and Discussion

The LCC Calculator results for incorporating a 1000W PV panel system are summarized in the Table below (see Appendix B, Case Study No. 11, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The base case investment generated a slightly negative net present value and internal rate of return of 11.6%. The simple payback period for the investment was found to be 9 years or about two-fifths of the service life of the PV technology. The PV system failed to meet the desired hurdle rate for investment.

LCC Results for MURB – 1000W PV Panel Installation

	LCC Results
Net present value at yr 25	$(2,272)
Payback period	9 yrs
Internal rate of return	11.6%

4.2.7 Case Study No. 12: Install Dual Flush Toilets

Background and Technology Description

Conventional toilets are designed to rely on gravity to clear the bowl. Essentially, a toilet consists of a storage container which is located above the bowl, and the bowl itself. When the toilet is flushed, the storage container is rapidly drained into the bowl, which is subsequently drained to a sewer or septic system. This type of system utilizes the same amount of water regardless of the degree to which the bowl must be emptied.

Dual flush toilets differ from conventional toilets in that they have two different flush volumes: the user has the option of selecting a reduced volume flush, typically for liquids only. While simple in concept, dual flush toilets represent mechanical challenges to toilet manufacturers. Some manufacturers utilize systems that employ a siphonic flush, which essentially pulls the waste out of the bowl.

The use of dual flush toilets results in potable water use reductions, which in turn results in the following environmental benefits.

- The creation and use of potable water results in treatment chemical use (chlorine, alum, fluoride), lowering of natural waterways or aquifers (dependent on the source of water), and small amounts of energy use (for pumping). Reduction in potable water use will reduce these effects.
- Potable water supply typically requires some energy use (for pumping). Reduction in potable water use will reduce these effects.

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below:

- Investment period: 25 years. This represents the approximate serviceable life of dual flush toilets.
- It is recognized that there is a large fluctuation in the capital costs associated with both standard and dual flush toilets. After consultation with costing books (RSMeans), and a major dual flush toilet manufacturer (Caroma), we developed the assumption that a dual flush toilet will cost approximately $100 more than a conventional toilet.
- Water savings based on a family of four, with each person flushing five times per day.
- The building is located in Ottawa.

The cost variables listed in the Table below were entered into the “LCC Calculator”.

Cost Variables

	Dual Flush
Incremental capital cost	$100
Expected life	25 yrs
Annual maintenance cost	$0
Annual water cost savings	$15

Note: Annual savings determined from reduced water usage and cost of water (i.e., 3 L/flush x $0.692/m^3 x 0.001m^3/L water charge x 20 flushes/day x 365 days/year).

LCC Results and Discussion

The LCC Calculator results for installing a dual flush toilet are summarized in the Table below (see Appendix B, Case Study No. 12, for a screen capture of investment criteria, input values and LCC results pertaining to this case study). The installation of a dual flush toilet generated a positive net present value and internal rate of return. The simple payback period for the investment is 6.1 years. These financial indicators surpass the minimum investment cut-off criteria set out for the analysis, suggesting that other green technologies may well be a better investment than dual flush toilets.

LCC Results for MURB – Dual Flush Toilet Installation

	LCC Results
Net present value at yr 25	$16
Payback period	6.1
Internal rate of return	17.4%

4.2.8 Case Study No. 13: Green Roof

Background and Technology Description

Green roofs are generally regarded as good for the environment. The benefits of a green roof include lower cooling load, reduced roof temperature, reduced heat island effect, potentially longer roof membrane life, and reduced peak intensity and overall volume of stormwater discharge. The point of this pre-feasibility life cycle costing investigation is to show how the LCC tool can be used to determine whether the direct future cost savings associated with a green roof investment warrant its higher initial capital cost.

A number of the benefits ascribed to green roofs – reduced storm water run-off, heat island mitigation, generally improved aesthetics, and greater access to the outdoors – do not lend themselves to immediate monetary estimation and do not accrue to the initial investor, but rather to society as a whole[5]. These non-monetary returns or externalities are beyond the scope of this LCC analysis, which deals only with those cost savings that

[5] For more information on quantifying these societal benefits see:
"Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto", prepared by Ryerson University, October 2005, and "Making Green Roofs Happen: A discussion paper presented to Toronto's Round Table on the Environment", November 2005.
(www.cityoftoronto/greenroofs)

can be estimated and recouped directly by the private investor. The identified direct monetary benefits (savings) of green roofs accruing to the investor are lower annual maintenance costs and energy cost savings.

Green roofs are still a relatively new phenomenon in North America, and every green roof is a one-of-a-kind installation. For both green and conventional roofs, costs can vary considerably depending on the type of roof, the area to be roofed, its perimeter detail, the number of penetrations through the roof, and the height of the building. This LCC assumes a roofing area of $385m^2$ with a perimeter of 85m (typical high rise condominium footprint).

An extensive green roof is an alternative protected membrane roof[6]. Inverted or protected membrane roofs first gained popularity in North America during the 1970s. These roofs are primarily composed of a number of different material layers. The first layer is the membrane itself, which either floats on, or is adhered to, the roof deck. Rigid insulation is then placed on top of the membrane with a filter fabric on top of the insulation. Lastly, concrete pavers or stone aggregates are placed on the roof to act as ballast. These roofs traditionally last about five years longer than their conventional, exposed membrane counterparts as they are not subject to the same wear, temperature fluctuations or breakdown due to direct UV radiation. An extensive green roof incorporates an additional root barrier and drainage layer and replaces the ballast with a growing medium (150mm or less in thickness) and plant material.

Assumptions and Costs

In order to prepare this LCC analysis a number of assumptions were necessary; they are listed below.

- Investment period: 40 years (expected life of green roof).
- General price inflation: to average 2.5% over the investment period.
- Electricity price inflation: to average 5% over the investment period.
- Discount (hurdle) rate: assumed to be 8%.
- Financing costs excluded from analysis.
- Service life of roofs (Toronto):
    - traditional inverted roof – 22 years
    - extensive green roof – 40 years[7].
- Traditional inverted roofing system replacement costs set at 80% of original cost (accounts for some reuse of ballast and insulation material).

---

[6] Another green roof type is commonly referred to as an “intensive” green roof. While not assessed here, an intensive green roof involves considerably deeper growing medium, the mass of which will often surpass the design load carrying capabilities of a typically constructed roof. Hence, there is a considerable difference in costs associated with an intensive green roof relative to an extensive green roof.

[7] While European anecdotal evidence is suggestive of a 40-year life span for green roofs, there is no conclusive documentation of this extended service life in a North American setting. Greater expected life is an often-quoted benefit of green roofs, so we have used a 40-year life span for the green roof to maximize the potential for a greater expected life to affect the LCC comparison.

- Residual value of traditional roof was estimated as a function of its remaining service life at the end of the study period and its last replacement cost adjusted for general inflation.

The cost variables listed in the Table below were entered into the "LCC Calculator". The various sources for the information to frame the analysis are listed in the notes accompanying the Table.

Cost Variables (assumes gross roof area of 385 m^2 and roof perimeter of 85m)

	Traditional inverted roof	Extensive green roof
Installed capital cost	$38,950	$72,380
Installed cost / m^2	$113	$188
Expected life	22yrs, replaced at year 23	40 yrs
Annual maintenance cost	$390	$202
Annual energy cost savings	-	$163

Notes:
Traditional inverted roof – the initial installed capital cost, estimated at $75 (low) and $150 (high) per m^2, was averaged for purposes of the analysis. Includes membrane, 100XPS insulation, filter fabric and gravel ballast[8]. Source for expected life: "Maintenance, Repair and Replacement Effects for Building Envelope Materials". Prepared for the Athena Institute by Morrison Hershfield Ltd. Jan./02). Annual maintenance cost estimated at 1% of capital cost.
Extensive green roof – total installed capital cost estimated at $116 (low) and $405 (high) per m^2 – used $188/ m^2 of roof (equivalent to $75/ m^2 over the cost of traditional inverted roof). Source: "Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto", prepared by Ryerson University, October, 2005. Annual Maintenance cost — annualised value for plant maintenance during first two years. Source: "CMHC Design Guidelines for Green Roofs" (S. Peck and M. Kuhn). Annual energy cost savings calculated at $0.42/ m^2 (saving 4.15kWh/ $m^2$of roof @ $0.1017/kWh). Source: Ryerson University report cited above.

LCC Results and Discussion

Obviously, a roof is an essential element for any building. Therefore, the most suitable roof is one that provides the required performance at the least cost on a life cycle basis. So the question is, do the direct monetary savings and longer expected life ascribed to the green roof warrant its higher capital cost? The LCC results of the two roofing scenarios are presented in the Table below (see Appendix B, Case Study No. 13, for a screen capture of investment criteria, input values and LCC results pertaining to this case study).

LCC Results for Traditional and Extensive Green Roof

	Traditional inverted roof	Extensive green roof
Net present value at yr 40	$(54,738)	$(71,823)
Payback period	greater than study period	greater than study period
Internal rate of return	-14.3%	-6.8%

Neither roof generated a positive net present value, although the traditional inverted roof resulted in the lowest life cycle cost over a 40-year period. The higher capital cost of the

[8] Typical roofing cost sources include RS Means construction cost estimator as well as roofing contractors and roofing membrane manufacturers.

green roof was not offset enough by its lower maintenance cost, energy savings or its longer expected life. Neither roofing option generated a payback within the study period time frame; this fact reflects the cost nature of a roof. Both roof cost scenarios also generated a negative internal rate of return, with the green roof generating a less negative return due to positive cash flows related to its energy savings.

These results indicate that without incentives or subsidies, green roofs are not a viable economic alternative to traditional roofing solutions. Essentially, too few of the benefits of green roofs accrue to the investor. It is for this reason that many municipalities provide, or are contemplating providing, incentives and subsidies for green roof installations to properly account for the additional benefits of green roofs that accrue to society.

In the case of the green roof analysis above, it was determined using the LCC Calculator that either the green roof's net annual energy savings needed to be in the order of $850 per year ($2.20/m^2/yr), or its installed capital cost needed to be in the order of $55,000 to generate a NPV similar to that of the traditional roof. Or, to put it another way, either the annual benefits associated with a green roof accruing to the investor need to increase by some $700 per year ($1.80/m^2/yr), or the green roof installation needs to receive an initial capital cost subsidy of about $17,500 ($42/m^2), before the green roof's NPV approaches that of the traditional roof. These kinds of financial incentives can be readily estimated using the LCC calculator. Alternatively, incentives that are offered can be incorporated in the calculator to assess their effect, as long as they can be monetized.

Resources and Links

Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto, prepared by Ryerson University, October 2005. (www.cityoftoronto/greenroofs

Making Green Roofs Happen: A discussion paper presented to Toronto's Round Table on the Environment, November 2005. (www.cityoftoronto/greenroofs)

Regent Park Plan: Green Roof Life Cycle Costing Report. October 2004 -Appendix 9. www.regentparkplan.ca/pdfs/sustain/appendix9.pdf

CMHC Design Guidelines for Green Roofs (S. Peck and M. Kuhn).

www.cmhc-schl.gc.ca/en/imquaf/himu/upload/Design-Guidelines-for-Green-Roofs.pdf

Green roofs web portal www.greenroofs.com/

Green Roofs for Healthy Cities – www.greenroofs.net

Appendix A

RETScreen Software

The **RETScreen International Clean Energy Project Analysis Software** is a unique decision support tool developed by Natural Resources Canada in partnership with a number of international agencies. The software, provided free-of-charge, can be used worldwide to evaluate the energy production, life cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs). The software also includes product, cost and weather databases, as well as a detailed online user manual.

Product Data

The RETScreen International Online Product Database provides contact information for more than 1,000 clean energy technology manufacturers around the globe, including direct website and internet links from within the RETScreen software. In addition, the database provides access to pertinent product performance and specifications data for a number of these manufacturers. These data can be "pasted" into the relevant cells within the RETScreen software. The database is accessed directly through the RETScreen software models available for each of the technologies. Currently, the software supports assessment of the following technologies:

- wind turbines, towers, rotors, etc.;
- small hydro turbines;
- photovoltaic modules;
- solar air heating systems (i.e. Solarwall®);
- biomass heating systems;
- windows for passive solar heating;
- combined heat and power (district heating);
- solar water heaters (including pool heaters); and
- ground-source heat pumps.

The product database is distributed for informational purposes only. Some of the cost data for the various technologies go back as far as 2000 and have not been updated since then, so relying on this cost data alone would not be recommended.

Weather Data

The RETScreen International Online Weather Database provides users access to weather data from more than 1,000 ground monitoring stations around the world – all major cities in Canada are covered. These data are critical for assessing the amount of energy a clean energy technology project is expected to produce (e.g., wind turbine, PV). These data may also be directly "pasted" into the pertinent cells within the RETScreen software. For more remote areas, weather data may be directly copied from the NASA website and then "pasted" into the applicable RETScreen spreadsheets, or entered manually. The use of these data results in substantial time and cost savings for RETScreen users.

The weather databases provide daily, monthly and/or annual average values used to run the RETScreen models, e.g., heating degree days, wind speed, etc.

Assessment

RETScreen's decision support tool is a set of linked spreadsheets that simplify the process of assessing the viability of renewable energy technologies. RETScreen often uses an incremental approach in its economic assessment; i.e., instead of running a conventional and renewable technology separately through a financial analysis and then comparing them, it will often take an incremental benefit approach, using a net capital cost difference between two technologies and the consequential energy savings between the two systems.

Despite all the help (on-line user manual provided), on-line links to manufacturers and weather data, the knowledge base required to complete a pre-feasibility analysis is still extensive and beyond the lay knowledge of a typical builder/developer in consultation with a potential consumer of one of these renewable technologies. But due to the weather-related specifics of a lot of these technologies, RETScreen offers the most efficient and effective method for sizing up the applicability of these technologies.

Appendix B

Case Study LCC Calculator Screen Captures

Note: The screen captures below are best viewed at 125% (or greater) of the normal (100%) view setting on your computer screen. Please change your view setting accordingly.

Single Family Home – Case Study No. 1: Improved Air Sealing

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	SFH- Air sealing		
Date &Time	1/02/06 9:30		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	30		
Applicable discount (hurdle) rate (%)	8		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	SFH - Air sealing		
Total installed capital cost	$ 550		
Initial cash investment amount	$ 550		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ -		
Annual thermal fuel energy savings or (cost)	$ 750		
Annual maintenance (costs) or savings	$ -		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%		
NPV for study period (yrs)	30 $ 25,488		
NPV at year (one-third of study period)	10 $ 7,343		
NPV at year (two-thirds of study period)	20 $ 15,998		
Simple Payback Period on initial **cash** (yrs)	0.7		
Simple Payback Period on **total** project (yrs)	0.7		
Internal Rate of Return on Investment (%)	157.6%		

Single Family Home – Case Study No. 2: Upgraded Exterior Wall Insulation

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	SFH- Added R-8 Exterior Insulation		
Date &Time	1/02/06 15:00		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	30		
Applicable discount (hurdle) rate (%)	8		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	SFH- Added Exterior Insulation		
Total installed capital cost	$ 8,500		
Initial cash investment amount	$ 8,500		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ -		
Annual thermal fuel energy savings or (cost)	$ 400		
Annual maintenance (costs) or savings	$ -		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%		
NPV for study period (yrs)	30 $ 5,387		
NPV at year (one-third of study period)	10 $ (4,291)		
NPV at year (two-thirds of study period)	20 $ 325		
Simple Payback Period on initial **cash** (yrs)	11.7		
Simple Payback Period on **total** project (yrs)	11.7		
Internal Rate of Return on Investment (%)	11.6%		

Single Family Home - Case Study No. 3: Upgrade to High Efficiency Furnace+HRV

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	SFH- Upgrade furnace and add HRV		
Date &Time	1/02/06 15:28		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	20		
Applicable discount (hurdle) rate (%)	8		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	SFH- Upgrade furnace and add HRV		
Total installed capital cost	$ 1,000		
Initial cash investment amount	$ 1,000		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ 20		
Annual thermal fuel energy savings or (cost)	$ 480		
Annual maintenance (costs) or savings	$ (10)		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%		
NPV for study period (yrs)	20 $ 9,722		
NPV at year (one-third of study period)	6 $ 2,027		
NPV at year (two-thirds of study period)	13 $ 5,757		
Simple Payback Period on initial **cash** (yrs)	1.8		
Simple Payback Period on **total** project (yrs)	1.8		
Internal Rate of Return on Investment (%)	62.2%		

Single Family Home – Case Study No. 4: Solar Hot Water Heating

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA Scenario 1	Scenario 2	Scenario 3
Project Name	SFH- Solar Hot Water Heating		
Date &Time	1/02/06 15:28		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	25		
Applicable discount (hurdle) rate (%)	8		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	SFH- Solar Hot Water Heating		
Total installed capital cost	$ 4,500		
Initial cash investment amount	$ 4,500		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ (6)		
Annual thermal fuel energy savings or (cost)	$ 100		
Annual maintenance (costs) or savings	$ (20)		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%		
NPV for study period (yrs)	25 $ (2,033)		
NPV at year (one-third of study period)	8 $ (3,832)		
NPV at year (two-thirds of study period)	16 $ (3,045)		
Simple Payback Period on initial **cash** (yrs)	19.3		
Simple Payback Period on **total** project (yrs)	19.3		
Internal Rate of Return on Investment (%)	3.7%		

Single Family Home — Case Study No. 5: Rainwater Collection System

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	SFH - Rainwater harvesting with **50%** capital cost rebate	SFH - Rainwater harvesting with **no** capital cost rebate	
Date &Time	1/02/06 21:03	1/02/06 21:03	
Completed by:	Jamie Meil	Jamie Meil	
Company	Athena Institute	Athena Institute	
Contact phone number	613.722.8075	613.722.8076	
Contact email	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca	
Study Period in years	20	20	
Applicable discount (hurdle) rate (%)	8	8	
General price inflation factor (%)	2.5	2.5	
Thermal fuel energy price inflation factor (%)	9	9	
Electricity price inflation factor (%)	3	3	
INVESTMENT DATA			
Investment Name (description)	SFH - Rainwater harvesting with 50% capital cost rebate	SFH - Rainwater harvesting with no capital cost rebate	
Total installed capital cost	$ 100	$ 200	
Initial cash investment amount	$ 100	$ 200	
Capital portion financed	$ -	$ -	
financing annual interest rate (%)	0.00%	0.00%	
financing (amortization) period in yrs	$ -	$ -	
Annual Financing costs	$0	$0	
Annual electricity energy savings or (cost)	$ -	$ -	
Annual thermal fuel energy savings or (cost)	$ -	$ -	
Annual maintenance (costs) or savings	$ -	$ -	
Other annual (costs) or savings	$ 20	$ 20	
Replacement interval in years	-	-	
Periodic Replacement cost	$ -	$ -	
Periodic Salvage value	$ -	$ -	
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%	at a discount rate of 8%	
NPV for study period (yrs)	20 $ 142	20 $ 42	
NPV at year (one-third of study period)	6 $ 0	6 $ (100)	
NPV at year (two-thirds of study period)	13 $ 84	13 $ (16)	
Simple Payback Period on initial **cash** (yrs)	4.7	8.8	
Simple Payback Period on **total** project (yrs)	4.7	8.8	
Internal Rate of Return on Investment (%)	22.4%	10.4%	

MURB - Case Study No. 7: Upgraded Window System

CMHC Life Cycle Cost Calculator			
developed by the Athena Institute	yellow "shaded" cells to be completed by the tool user		
	violet "shaded" cells are calculated by model		
	orange "shaded" cells represent default values, changable by user		
COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - install upgraded window system		
Date &Time	2/02/06 9:49		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	25		
Applicable discount (hurdle) rate (%)	15		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	MURB - install upgraded window system		
Total installed capital cost	$ 25,000		
Initial cash investment amount	$ 25,000		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ 1,600		
Annual thermal fuel energy savings or (cost)	$ 8,400		
Annual maintenance (costs) or savings	$ (100)		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 15%		
NPV for study period (yrs)	25 $ 99,713		
NPV at year (one-third of study period)	8 $ 35,753		
NPV at year (two-thirds of study period)	16 $ 73,542		
Simple Payback Period on initial **cash** (yrs)	2.2		
Simple Payback Period on **total** project (yrs)	2.2		
Internal Rate of Return on Investment (%)	51.0%		

MURB — Case Study No. 8: Upgrade to Condensing Boiler System

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - Condensing Boiler Installation		
Date &Time	2/02/06 10:06		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	30		
Applicable discount (hurdle) rate (%)	15		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	MURB - Condensing Boiler Installation		
Total installed capital cost	$ 25,000		
Initial cash investment amount	$ 25,000		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ -		
Annual thermal fuel energy savings or (cost)	$ 6,000		
Annual maintenance (costs) or savings	$ (100)		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 15%		
NPV for study period (yrs)	30 $ 61,364		
NPV at year (one-third of study period)	10 $ 19,655		
NPV at year (two-thirds of study period)	20 $ 45,937		
Simple Payback Period on initial **cash** (yrs)	3.5		
Simple Payback Period on **total** project (yrs)	3.5		
Internal Rate of Return on Investment (%)	34.8%		

MURB - Case Study No. 9: Install HRV in Individual Suites

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - install HRV in each suite	MURB - install HRV in each suite, at 50% energy savings	
Date &Time	2/02/06 10:52	2/02/06 10:52	
Completed by:	Jamie Meil	Jamie Meil	
Company	Athena Institute	Athena Institute	
Contact phone number	613.722.8075	613.722.8076	
Contact email	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca	
Study Period in years	20	20	
Applicable discount (hurdle) rate (%)	8	8	
General price inflation factor (%)	2.5	2.5	
Thermal fuel energy price inflation factor (%)	9	9	
Electricity price inflation factor (%)	3	3	
INVESTMENT DATA			
Investment Name (description)	MURB - install HRV in each suite	MURB - install HRV in each suite, at 50% energy savings	
Total installed capital cost	$ 1,000	$ 1,000	
Initial cash investment amount	$ 1,000	$ 1,000	
Capital portion financed	$ -	$ -	
financing annual interest rate (%)	0.00%	0.00%	
financing (amortization) period in yrs	$ -	$ -	
Annual Financing costs	$0	$0	
Annual electricity energy savings or (cost)	$ 100	$ 50	
Annual thermal fuel energy savings or (cost)	$ 300	$ 150	
Annual maintenance (costs) or savings	$ (10)	$ (10)	
Other annual (costs) or savings	$ -	$ -	
Replacement interval in years	-	-	
Periodic Replacement cost	$ -	$ -	
Periodic Salvage value	$ -	$ -	
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%	at a discount rate of 8%	
NPV for study period (yrs)	20 $ 6,760	20 $ 2,820	
NPV at year (one-third of study period)	6 $ 1,319	6 $ 134	
NPV at year (two-thirds of study period)	13 $ 4,018	13 $ 1,463	
Simple Payback Period on initial **cash** (yrs)	2.3	4.3	
Simple Payback Period on **total** project (yrs)	2.3	4.3	
Internal Rate of Return on Investment (%)	49.7%	27.8%	

MURB - Case Study No. 10: Install Drain Water Heat Recovery System

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - Drain water heat recovery	MURB - Drain water heat recovery at 50% of energy savings	
Date &Time	2/02/06 11:01	2/02/06 11:01	
Completed by:	Jamie Meil	Jamie Meil	
Company	Athena Institute	Athena Institute	
Contact phone number	613.722.8075	613.722.8076	
Contact email	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca	
Study Period in years	30	30	
Applicable discount (hurdle) rate (%)	15	15	
General price inflation factor (%)	2.5	2.5	
Thermal fuel energy price inflation factor (%)	9	9	
Electricity price inflation factor (%)	3	3	
INVESTMENT DATA			
Investment Name (description)	MURB - Drain water heat recovery	MURB - Drain water heat recovery at 50% of energy savings	
Total installed capital cost	$ 1,000	$ 1,000	
Initial cash investment amount	$ 1,000	$ 1,000	
Capital portion financed	$ -	$ -	
financing annual interest rate (%)	0.00%	0.00%	
financing (amortization) period in yrs	$ -	$ -	
Annual Financing costs	$0	$0	
Annual electricity energy savings or (cost)	$ -	$ -	
Annual thermal fuel energy savings or (cost)	$ 180	$ 90	
Annual maintenance (costs) or savings	$ -	$ -	
Other annual (costs) or savings	$ -	$ -	
Replacement interval in years	-	-	
Periodic Replacement cost	$ -	$ -	
Periodic Salvage value	$ -	$ -	
FINANCIAL RESULTS SUMMARY	at a discount rate of 15%	at a discount rate of 15%	
NPV for study period (yrs)	30 $ 1,615	30 $ 307	
NPV at year (one-third of study period)	10 $ 356	10 $ (322)	
NPV at year (two-thirds of study period)	20 $ 1,150	20 $ 75	
Simple Payback Period on initial **cash** (yrs)	4.4	7.5	
Simple Payback Period on **total** project (yrs)	4.4	7.5	
Internal Rate of Return on Investment (%)	28.5%	17.9%	

MURB - Case Study No. 11: Install a 1000W PV System

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - 1000W PV Panel Installation		
Date &Time	9/03/06 11:06		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	25		
Applicable discount (hurdle) rate (%)	15		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	MURB - 1000W PV Panel Installation		
Total installed capital cost	$ 10,000		
Initial cash investment amount	$ 10,000		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ 1,000		
Annual thermal fuel energy savings or (cost)	$ -		
Annual maintenance (costs) or savings	$ (40)		
Other annual (costs) or savings	$ -		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 15%		
NPV for study period (yrs)	25 $ (2,272)		
NPV at year (one-third of study period)	8 $ (5,168)		
NPV at year (two-thirds of study period)	16 $ (3,165)		
Simple Payback Period on initial **cash** (yrs)	9.0		
Simple Payback Period on **total** project (yrs)	9.0		
Internal Rate of Return on Investment (%)	11.6%		

MURB - Case Study No. 12: Install a Dual Flush Toilet

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	MURB - Dual Flush Toilet Installation		
Date &Time	6/02/06 10:25		
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	25		
Applicable discount (hurdle) rate (%)	15		
General price inflation factor (%)	2.5		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	MURB - Dual Flush Toilet Installation		
Total installed capital cost	$ 100		
Initial cash investment amount	$ 100		
Capital portion financed	$ -		
financing annual interest rate (%)	0.00%		
financing (amortization) period in yrs	$ -		
Annual Financing costs	$0		
Annual electricity energy savings or (cost)	$ -		
Annual thermal fuel energy savings or (cost)	$ -		
Annual maintenance (costs) or savings	$ -		
Other annual (costs) or savings	$ 15		
Replacement interval in years	-		
Periodic Replacement cost	$ -		
Periodic Salvage value	$ -		
FINANCIAL RESULTS SUMMARY	at a discount rate of 15%		
NPV for study period (yrs)	25 $ 16		
NPV at year (one-third of study period)	8 $ (26)		
NPV at year (two-thirds of study period)	16 $ 3		
Simple Payback Period on initial **cash** (yrs)	6.1		
Simple Payback Period on **total** project (yrs)	6.1		
Internal Rate of Return on Investment (%)	17.4%		

MURB - Case Study No. 13: Green Roof

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, changable by user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	Traditional inverted roof	Extensive green roof	
Date &Time	2/02/06 14:12	2/02/06 14:12	
Completed by:	Jamie Meil	Jamie Meil	
Company	Athena Institute	Athena Institute	
Contact phone number	613.722.8075	613.722.8076	
Contact email	jamie.meil@athenaSMI.ca	jamie.meil@athenaSMI.ca	
Study Period in years	40	40	
Applicable discount (hurdle) rate (%)	8	8	
General price inflation factor (%)	2.5	2.5	
Thermal fuel energy price inflation factor (%)	3.5	3.5	
Electricity price inflation factor (%)	5	5	
INVESTMENT DATA			
Investment Name (description)	Traditional inverted roof	Extensive green roof	
Total installed capital cost	$ 38,950	$ 72,380	
Initial cash investment amount	$ 38,950	$ 72,380	
Capital portion financed	$ -	$ -	
financing annual interest rate (%)	0.00%	0.00%	
financing (amortization) period in yrs	$ -	$ -	
Annual Financing costs	$0	$0	
Annual electricity energy savings or (cost)	$ -	$ 163	
Annual thermal fuel energy savings or (cost)	$ -	$ -	
Annual maintenance (costs) or savings	$ (390)	$ (202)	
Other annual (costs) or savings	$ -	$ -	
Replacement interval in years	22	40	
Periodic Replacement cost	$ 31,160	$ -	
Periodic Salvage value	$ -	$ -	
FINANCIAL RESULTS SUMMARY	at a discount rate of 8%	at a discount rate of 8%	
NPV for study period (yrs)	40 $ (54,738)	40 $ (71,823)	
NPV at year (one-third of study period)	13 $ (42,534)	13 $ (72,487)	
NPV at year (two-thirds of study period)	26 $ (54,218)	26 $ (72,215)	
Simple Payback Period on initial **cash** (yrs)	Payback > study period	Payback > study period	
Simple Payback Period on **total** project (yrs)	Payback > study period	Payback > study period	
Internal Rate of Return on Investment (%)	-14.3%	-6.8%	

Appendix C

LCC Calculator Users' Guide

Applying Life Cycle Costing (LCC)

A Step-By-Step Guide to the use of

the CMHC LCC Calculator

Prepared for:

Canada Mortgage and Housing Corporation

By:

ATHENA SUSTAINABLE MATERIALS INSTITUTE

December, 2005

CONTENTS

1 Introduction

The purpose of this guide is to help users of the Life Cycle Cost (LCC) Calculator start using it effectively to evaluate various building related investment scenarios. The Calculator focuses on long timeframes, real monetary savings, and financial returns attributed to the use of green technologies in residential buildings.

This quick-start guide explains the various input data requirements and results generated by the tool. For case study examples completed using this tool, see the report entitled "green technologies (in development)……". The LCC Calculator is a set of linked Excel© based spreadsheets. This guide presumes that the user is acquainted with Excel.

2 Getting Started

2.1 Overview

There are many different methods for evaluating investment decisions, and many different measures that can be used. This tool deals with the life cycle costing (LCC) method.

LCC is an economic method for evaluating project investment alternatives over a selected period of time. It is particularly suited to determining whether the higher initial cost of an investment is justified by reductions in future costs (e.g., operating, maintenance, repair or replacement costs). It can also be used to compare alternatives with different initial and future costs.

The alternatives can be compared in various ways. The LCC Calculator uses three methods:

1. the Present Value (PV) of the entire stream of flows;
2. the Internal Rate of Return (IRR) on the investment; and
3. the simple payback period.

All of these measures are described in more detail later in this Guide.

The procedure for calculating an LCC can be summarized in the following steps.

1. Identify the alternative investment scenarios and any operational limitations.
2. Establish basic financial assumptions for the analysis.
3. Compile all relevant cost data for each of the scenarios to be considered.
4. Compare the LCCs for each alternative to determine the one with the lowest LCC.
5. Make a final decision, based on the LCC result as well as any risk, uncertainty or unquantifiable effects that may have a bearing on the decision.

The LCC result is expressed in present value[1] terms for a selected timeframe and discount rate. Typically, an LCC evaluation considers the following investment data and assumptions:

- Study period — investor's holding period or expected life of technology
- Discount/'hurdle' rate — investor's time preference for money
- Uncertainty *vs.* risk
- Inflation rate — general plus energy price inflation (in the case of an energy-related investment)
- Investment cost data — initial cash investment and total installed capital cost
- Financing data — financed amount, interest rate, loan duration, annual loan payment
- Depreciation (for an after tax analysis)
- Residual or resale value
- Recurring operation and maintenance costs
- Periodic replacement cost (if applicable)

The LCC Calculator tool utilizes four linked worksheets. The first worksheet, "LCC assumptions and results", is where the user enters the required information and gets back the results of the life cycle cost calculation. In this worksheet you can see the present value, simple payback period and internal rate of return results for up to three investment scenarios.

Each of the three "Results Calculator" sheets show the annual cash flows by cost element, the resultant total cash flow for individual years on both a nominal (unadjusted) and discounted basis, and the calculated the life cycle cost results for the investment over the expected life – up to 60 years. Each "Result Calculator" sheet corresponds to one of the three investment scenarios indicated on the first "LCC assumptions and results" sheet. These "Results Calculator" sheets provide a level of transparency so the user can verify inputs used in the calculation of the various financial measures.

2.2 Input Requirements

This section describes each of the major data element fields used in the process of completing an LCC assessment using the CMHC LCC Calculator. It is recommended that users have the Calculator open while reviewing this section.

The "LCC assumptions and results" sheet is divided into three sections: Description + Common Assumptions, Investment Data, and Financial Results Summary. The calculator is capable of analysing three investment scenarios side-by-side – Scenario 1, Scenario 2, and Scenario 3.

The next two sub-heading sections describe the input requirements for the Calculator, with the final section discussing the financial measures and their interpretation.

---

[1] The value in today's dollars of money to be spent or received in the future, recognizing that a dollar in the future may not be considered as valuable as a dollar today, even if there is no inflation. This is often called the "time value of money" or "time preference".

2.2.1 Description + Common Assumptions

Project Name – optional text field for description of the scenario to be evaluated
Date and Time – preset to current date and time
Completed by – optional text field to enter user/evaluator's name
Company - optional text field to enter company name
Contact phone number - optional text field to enter phone number
Contact email - optional text field to enter user/evaluator's email address

Study period in years [Enter a whole number, e.g., for 10 years, enter '10']
The study period indicates the number of years over which the investment scenario is to be assessed (minimum = 1 year; maximum = 60 years). The study period may either reflect the investor's time horizon[2] or the expected life of the technology being assessed (e.g., a photovoltaic array with an expected life of 25 years).

Applicable discount (hurdle) rate (%) [Enter a number, e.g., for 9%, enter '9']
The discount/hurdle rate is the rate of interest that makes an investor willing to invest a dollar today to get more than a dollar some time in the future. The discount/hurdle rate from a potential home owner's perspective could be the cost of capital (e.g., mortgage rate) or what he or she might receive from another investment vehicle of similar risk (e.g., Canada savings bonds for a low risk investment vs. the stock market for a higher risk investment). A building developer would typically use his or her company's average weighted cost of capital (debt and equity) adjusted for the perceived risk of the investment; alternatively, the company might already have a hurdle rate (required rate of return) policy used to assess prospective investments. The entered discount rate is used to discount all future annual cash flows in order to calculate the present value of the investment.

General price inflation factor (%) [Enter a number, e.g., for 3.5%, enter '3.5']
The user enters the annual inflation rate over the life of the project. North American general consumer price inflation (excluding energy) has averaged between 2 and 3% for the last 10 years. The LCC Calculator includes a preset default value of 2.5% for non-energy price inflation. The default value is only a suggested rate and may be changed by the user. Since 1990, Canadian general price inflation has average 2.2% per year. (Source: www.bankofcanada.ca.)

Thermal fuel energy price inflation factor (%) [Enter a number, e.g., for 3%, enter '3']
This is the annual energy price inflator to be used to escalate the cost of thermal fuels (oil, natural gas, coal) over the study period. Since 1992, Canadian residential natural gas prices have increased by 9% annually on average. (Source: Natural Resources Canada, Office of Energy Efficiency.) The LCC Calculator includes a preset default value of 9% for thermal fuel energy price inflation; however, the default value is only a suggested rate and may be changed by the user. According to Energyshop.ca, Canadian natural gas prices are forecast to jump by as much as 30% over the course of 2005 and 2006.

---
[2] The expected length of time a sum of money is to be invested.

Electricity price inflation factor (%) [Enter a number, e.g., for 3%, enter '3']
This is the annual energy price inflator to be used to escalate the cost of electricity over the study period. Since 1992, Canadian residential electricity prices have increased by 3% annually. (Source: Natural Resources Canada, Office of Energy Efficiency.) The default value for electricity price inflation has therefore been set at 3%.

2.2.2 Investment Data

Investment Name (description) – optional text field used to describe the specifics of the investment scenario to be evaluated.

Total installed capital cost [Enter a dollar value, e.g., for $10,000, enter '10000']
This value represents the total investment necessary to make the technology operational. The cost entered should be less any capital subsidy or rebate received. The Calculator assumes the installed capital cost occurs at the beginning of year 1.

Initial cash investment amount [Enter a dollar value, e.g., for $10,000, enter '10000']
This is the initial cash investment made by the investor. The Calculator assumes the initial investment amount occurs at the beginning of year 1.

Capital portion financed This dollar value is calculated by the Calculator. This value is the difference between the total installed capital cost and the initial cash investment amount, i.e., the capital portion to be financed. If the total installed capital cost and initial cash investment are the same, i.e., the investment is to be made entirely from cash savings on hand, the result will be zero. If this is the case, the user may skip entering data for the next two fields: annual interest rate and financing period. Capital portion financed is deemed to occur at the beginning of year one.

Financing annual interest rate (%) [Enter a number, e.g., for 3%, enter '3'] This is the annual interest (borrowing) rate charged on the financed portion of the investment.

Financing (amortization) period in years [Enter a whole number, e.g., for 5 years, enter '5'] This is the time period over which the financed portion (principal and interest) is to be repaid in full. Typically the amortization period is less than or equal to the study period chosen for the analysis.

Annual financing costs This is a fixed dollar value calculated by the Calculator. This is the fixed annual financing cost necessary to repay the financed portion of the project (including interest) at the stipulated annual interest rate applied to the loan over the loan amortization period indicated. Annual financing costs are modelled as though they occur at the end of each year.

Annual electricity energy savings or (costs) [Enter a dollar value, e.g., for an annual savings of $1,000, enter '1000'; for an annual cost of $1,000, enter '-1000']
This is a value calculated by the user for a technology. If the technology saves purchase electricity (e.g., installation of a photovoltaic array), enter the avoided annual purchased electricity amount (annual kWh saved x current price of electricity per kWh). If the

technology being assessed will consume electricity, enter the annual cost of electricity to employ the technology as a negative amount (e.g., a negative cash flow). If a technology both uses and saves electricity, enter the annual net electricity use (e.g., if the electricity cost savings are greater than the cost of electricity used, enter the net savings as a positive cash flow value). This value is escalated by the electricity inflation factor in future years.

Annual thermal fuel energy savings or (costs) [Enter a dollar value, e.g., for an annual savings of $1,000, enter '1000'; for an annual cost of $1,000, enter '-1000']
This is a value calculated by the user for the specified technology. If the technology saves (avoids) purchased thermal fuel (e.g., installation of a high efficiency furnace), enter the avoided annual purchased thermal fuel amount (annual m^3 of natural gas saved x current price of natural gas per m^3). If the technology being assessed will consume thermal fuel, enter the annual cost of fuel to employ the technology as a negative amount (e.g., a negative cash flow). This field value is escalated by the thermal fuel inflation factor in future years.

Annual maintenance (costs) or savings [Enter a dollar value, e.g., for an annual savings of $1,000, enter '1000'; for an annual cost of $1,000, enter '-1000']
The user enters the maintenance cost or savings applicable to the investment scenario. For an investment scenario incurring an annual maintenance cost, the user enters the cost as a negative annual cash flow. A maintenance cost savings is entered as a positive cash flow. The annual maintenance costs entry is subject to general price inflation in future years.

Other annual (costs) or savings [Enter a dollar value, e.g., for an annual savings of $1,000, enter '1000'; for an annual cost of $1,000, enter '-1000']
The user enters any other costs or savings applicable to the investment scenario. All cost information is entered as a negative cash flow, while a savings is entered as a positive cash flow. The annual other costs or savings entry is escalated by general price inflation.

Replacement interval in years [Enter a whole number, e.g., for 10 years, enter '10']
The replacement interval indicates the timing of periodic equipment replacement costs and any salvage (residual) value related to the replaced equipment. For example, for a 20-year study period where a major replacement occurs every five years, the replacement interval value is '5'; this scenario would result in four replacements.

Periodic Replacement cost [Enter a dollar value, e.g., for $1,000, enter '1000']
The user enters the periodic replacement cost in dollars. A periodic replacement cost represents a recurrent cost (negative cash flow) incurred at regular intervals (i.e., at the replacement interval) to maintain the technology. Periodic replacement costs are subject to the general price inflation escalator. For example, a furnace fan motor with an eight-year expected life has a replacement cost of $350; the Calculator computes that at year 8, the periodic replacement interval, the fan motor will cost ($\$350 \times 1.025^8$) — year 0 replacement cost multiplied by eight years of inflation.

Periodic salvage value [Enter a dollar value, e.g., for $1,000, enter '1000']
The user enters the periodic salvage value in dollars. A salvage value represents a positive cash flow recurring at regular intervals (i.e., replacement intervals) due to the salvage of a periodic replacement part. All salvage values are subject to the general price inflation escalator. For example, a fan motor in a furnace with an eight-year expected life has a salvage value of $50. The Calculator computes that, in year 8, the replacement interval, the salvage value of the fan motor will be ($\$50 \times 1.025^8$).

2.2.3 Financial Results Summary

NPV for study period (yrs), at one-third of study period, at two-thirds of study period – dollar value computed by the Calculator. These three rows calculate the net present value (NPV) of an investment scenario at three distinct periods over the study period (at the end of the study period, at one-third of the study period and at two-thirds of the study period). Using three periods shows when an investment begins to pay off. NPV is the net result of all future cash inflows minus the present value investment and any associated cash outflows. It considers the time value of money (discount rate) by taking into consideration such things as the cost of capital, interest rates and investment opportunity costs. The NPV is particularly sensitive to the discount rate. It recognizes that money has a cost (interest) and that an investor might prefer to have a dollar today versus having a dollar a year from now. If an investor is only willing to accept a 10% or better return on his or her investment, then he or she would be willing to invest a dollar today to receive $1.10 a year from now; this investor's time value of money (discount rate) is 10%. In other words, the "present value" of $1.10 a year from now is one dollar today in the mind of the investor. The larger the NPV – other things being equal – the more attractive the investment.

Simple payback period on initial cash investment (yrs) – the number of years required to pay back the initial *cash* investment, computed by the Calculator. This value indicates how many years are required to recover the initial cash investment for the project. Simple means that the measure is not sensitive to the time value of money – the discount rate. The simple payback period equates the net annual cash flows to the original cash investment to calculate the payback period before taxes. It determines net annual cash flows in any one year by subtracting the annual cost outflows, including the financing costs (debt repayment), from the total annual savings.

Essentially, the simple payback period method helps identify projects that will be unusually profitable or unprofitable early in their life. However, since the method ignores benefits and costs over the remaining service life of a project beyond the payback year, it imposes a bias against long-term projects with relatively long payback periods in favour of short-lived projects with quick paybacks. While the simple payback period should not be used as the primary indicator to evaluate a project, it is useful as a secondary measure to indicate the level of risk of an investment – a quicker payback period is usually an indicator of less risk.

Simple payback period on total project investment (yrs) – the number of years required to pay back the *total project* investment, computed by the Calculator. This payback measure differs from the initial cash investment payback measure in two significant ways: first, it is calculated assuming the total project cost was funded out of cash-on-hand – i.e., it assumes that no annual financing costs are involved; and second, it is calculated using the total project cost rather than just the initial cash investment. For this calculation, the Calculator assumes that the "initial cash investment" *is* the "total project cost"; therefore for projects where no financing charges are incurred, the two measures will report the same payback period.

Internal Rate of Return (IRR) on investment (%) – determines the discount (hurdle) rate achieved by the investment, calculated by the model. IRR is the flipside of the net present value (NPV) calculation and is based on the same principles and the same mathematics. NPV shows the value of a stream of future cash flows discounted back to the present by some percentage that represents the minimum desired rate of return or the cost of capital. The IRR, on the other hand, computes a break-even rate of return. The IRR is the rate at which the value of cash outflows equals the value of cash inflows. IRR should be compared to the investor's cost of capital or desired hurdle rate; i.e., the investor should avoid an investment in a project if its IRR is less than the cost of capital or minimum desired hurdle rate. The Calculator reports IRRs between –20% and +50%. If the calculated IRR is less than –20%, the Calculator will provide a message – "IRR not available-very negative".

3 Brief Case Study

This section provides a brief case study to demonstrate data requirements and use of the Calculator. This particular case study was taken from the RETScreen International website. It concerns an investment in a solar hot water heating system to offset some of the domestic hot water requirements for a single family home.

3.1 Case Study Description

Objective: to determine the financial viability of using a solar water heating system to offset some of the domestic hot water requirements for a single family home.

Site and system requirements information: The home is a185m2 two-storey single family dwelling with three occupants located in Vancouver, B.C. The roof has a pitch of 12 in 12 and faces due south. Currently a high-efficiency natural gas fired hot water heater exists in the home.

The solar system needs to operate year round in a freeze-protected configuration. The 150 L solar tank will be located on the ground floor – a distance of 3m from the solar collector. All piping will be copper with foam insulation. A small heat exchanger and pump will be used. The pump will have to be changed every 13 years at a cost of $350. The new glazed solar collector system is to be purchased with a life expectancy of 25 years (study period). It is estimated that the annual thermal energy offset will be equivalent to 236 m^3 of natural gas. The pump will consume the equivalent of 67 kWh/year.

Financial Information: The customers will purchase the system out of their cash savings (i.e., there will be no financing costs) at an installed cost of $4,617. The discount rate to be used will be equal to the current mortgage rate on the home (8%). The retail price of natural gas (the fuel to be offset) is $0.44/$m^3$. The retail price of electricity is $0.06/kWh (electricity will be consumed by the pump). The price of electricity and thermal energy are estimated to escalate by 3% and 9% per year, respectively. General inflation is expected to average 2.5% per year.

3.2 Case Study Results

The results below indicate that a solar hot water investment would not yield a reasonable return on investment. The NPV for the project is negative for a discount rate of 8%. The simple payback period is approximately 19 years – only six years short of the expected life for the system. And lastly, the IRR for the investment is only 4.1%, which is only half the cost of capital or the investors' desired hurdle rate of 8%.

If, on the other hand, the customers are only earning 3.5% on the savings account from which the funds are drawn, they might select that rate as the hurdle or discount rate. In that case, the investment would be more attractive.

CMHC Life Cycle Cost Calculator

developed by the Athena Institute

yellow "shaded" cells to be completed by the tool user
violet "shaded" cells are calculated by model
orange "shaded" cells represent default values, but may be changed by the tool user

COMMON ASSUMPTIONS	INPUT DATA		
	Scenario 1	Scenario 2	Scenario 3
Project Name	Retscreen case study- solar hot water		
Date &Time	10/03/06 14:47	10/03/06 14:47	10/03/06 14:47
Completed by:	Jamie Meil		
Company	Athena Institute		
Contact phone number	613.722.8075		
Contact email	jamie.meil@athenaSMI.ca		
Study Period in years	25		
Applicable discount (hurdle) rate (%)	8		
General price inflation factor (%)	2.2		
Thermal fuel energy price inflation factor (%)	9		
Electricity price inflation factor (%)	3		
INVESTMENT DATA			
Investment Name (description)	solar hot water-sfhome		
Total installed capital cost	$ 4,617		
Initial cash investment amount	$ 4,617		
Capital portion financed	$ -	$ -	$ -
financing annual interest rate (%)	0.00%	0.00%	0.00%
financing (amortization) period in yrs	$ -	$ -	$ -
Annual Financing costs	$0	$0	$0
Annual electricity energy savings or (cost)	$ (4)		
Annual thermal fuel energy savings or (cost)	$ 104		
Annual maintenance (costs) or savings	$ -	$ -	
Other annual (costs) or savings	$ -	$ -	$ -
Replacement interval in years	13		
Periodic Replacement cost	$ 350		
Periodic Salvage value	$ -	$ -	$ -
FINANCIAL RESULTS SUMMARY	at a discount rate of **8%**	at a discount rate of **0%**	at a discount rate of **0%**
NPV for study period (yrs)	25 $ (1,908)	0 $ -	0 $ -
NPV at year (one-third of study period)	8 $ (3,776)	0 $ -	0 $ -
NPV at year (two-thirds of study period)	16 $ (3,030)	0 $ -	0 $ -
Simple Payback Period on initial **cash** investment (yrs)	18.9	Payback > study period	Payback > study period
Simple Payback Period on **total** project investment (yrs)	18.9	Payback > study period	Payback > study period
Internal Rate of Return (IRR) on Investment (%)	4.1%	ıot available - very negative	available - very negative

CMHC Life Cycle Cost Calculator

Project Name: 0 Investment Name: 0

Project Initiation year	2005		
Discount (Hurdle) Rate	0	Salvage / Resale value ($)	$ - $ - $ - $ - $ - $ - $ -
General Price Inflation	0.025	Replacement Cost($)	$ - $ - $ - $ - $ - $ - $ -
Thermal fuel price inflation	0.035		
Electricity Price Inflation	0.05		
Study Period (years)	0	Replacement time (at year)	1 0 0 0 0 0

Year	Num.	Initial Equity Investment	Annual Maintenance	Annual Thermal Fuel Savings (cost)	Annual Electricity Fuel Savings (cost)	Financing Cost	Other Annual Benefit or (Cost)	Periodic Cost	Salvage or Resale Value	Total Annual Cash Flow	Discount Factor	Discount Results Present Value	Cummulative Discounted Cashflow	equity payback		total cost paybk	
		$ -	$ -	$ -	$ -	$ -	$ -				0%					0	
	0	$ -								$ -	1.0000	$ -	$ -				0
2005	1		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2006	2		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2007	3		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2008	4		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2009	5		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2010	6		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2011	7		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2012	8		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2013	9		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2014	10		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2015	11		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2016	12		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2017	13		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2018	14		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2019	15		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2020	16		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2021	17		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2022	18		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2023	19		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2024	20		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2025	21		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2026	22		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2027	23		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2028	24		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2029	25		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2030	26		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2031	27		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2032	28		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2033	29		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2034	30		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2035	31		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2036	32		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2037	33		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2038	34		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2039	35		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2040	36		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2041	37		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2042	38		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2043	39		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2044	40		$ -	$ -	$ -	$ -	$ -	$ -	$ 9,753	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2045	41		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2046	42		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2047	43		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2048	44		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2049	45		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2050	46		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2051	47		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2052	48		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2053	49		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2054	50		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2055	51		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2056	52		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2057	53		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2058	54		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2059	55		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2060	56		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2061	57		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2062	58		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2063	59		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
2064	60		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -	$ -	0.00	$ -	0.00
														0.00			0.00

CMHC Life Cycle Cost Calculator

Project Name: 0 Investment Name: 0

Project Initiation year	2005
Discount (Hurdle) Rate	0
General Price Inflation	0.025
Thermal fuel price inflation	0.035
Electricity Price Inflation	0.05
Study Period (years)	0

Salvage / Resale value ($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Replacement Cost($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Replacement time (at year)		1	0	0	0	0	0

Year	Num	$ -	$ -	$ -	$ -	$ -	$ -				0%	Discount Results	
		Initial Equity Investment	Annual Maintenance	Annual Thermal Fuel Savings (cost)	Annual Electricity Fuel Savings (cost)	Financing Cost	Other Annual Benefit or (Cost)	Periodic Cost	Salvage or Resale Value	Total Annual Cash Flow	Discount Factor	Present Value	Cummulative Discounted Cashflow
	0	$ -								$ -	1.0000	$ -	$ -
2005	1		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2006	2		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2007	3		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2008	4		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2009	5		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2010	6		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2011	7		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2012	8		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2013	9		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2014	10		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2015	11		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2016	12		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2017	13		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2018	14		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2019	15		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2020	16		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2021	17		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2022	18		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2023	19		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2024	20		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2025	21		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2026	22		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2027	23		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2028	24		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2029	25		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2030	26		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2031	27		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2032	28		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2033	29		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2034	30		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2035	31		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2036	32		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2037	33		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2038	34		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2039	35		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2040	36		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2041	37		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2042	38		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2043	39		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2044	40		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2045	41		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2046	42		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2047	43		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2048	44		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2049	45		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2050	46		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2051	47		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2052	48		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2053	49		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2054	50		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2055	51		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2056	52		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2057	53		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2058	54		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2059	55		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2060	56		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2061	57		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2062	58		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2063	59		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2064	60		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -

CMHC Life Cycle Cost Calculator

Project Name: 0 | Investment Name: 0

Project Initiation year	2005							
Discount (Hurdle) Rate	0	Salvage / Resale value ($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
General Price Inflation	0.025	Replacement Cost($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Thermal fuel price inflation	0.035							
Electricity Price Inflation	0.05							
Study Period (years)	0	Replacement time (at year)		1	0	0	0	0	0

Year	Num	$ -	$ -	$ -	$ -	$ -	$ -			Total	0%	Discount Results	Cummulative
		Initial Equity Investment	Annual Maintenance	Annual Thermal Fuel Savings (cost)	Annual Electricity Fuel Savings (cost)	Financing Cost	Other Annual Benefit or (Cost)	Periodic Cost	Salvage or Resale Value	Annual Cash Flow	Discount Factor	Present Value	Discounted Cashflow
	0	$ -								$ -	1.0000	$ -	$ -
2005	1		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2006	2		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2007	3		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2008	4		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2009	5		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2010	6		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2011	7		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2012	8		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2013	9		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2014	10		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2015	11		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2016	12		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2017	13		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2018	14		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2019	15		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2020	16		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2021	17		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2022	18		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2023	19		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2024	20		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2025	21		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2026	22		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2027	23		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2028	24		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2029	25		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2030	26		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2031	27		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2032	28		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2033	29		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2034	30		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2035	31		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2036	32		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2037	33		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2038	34		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2039	35		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2040	36		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2041	37		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2042	38		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2043	39		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2044	40		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2045	41		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2046	42		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2047	43		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2048	44		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2049	45		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2050	46		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2051	47		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2052	48		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2053	49		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2054	50		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2055	51		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2056	52		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2057	53		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2058	54		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2059	55		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2060	56		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2061	57		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2062	58		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2063	59		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -
2064	60		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	1.0000	$ -	$ -

Visit our website at www.cmhc.ca