



R

RESEARCH REPORT

STRATEGIES FOR REDUCING
BUILDING ENERGY USE VIA
INNOVATIVE BUILDING
ENVELOPE TECHNOLOGIES



HOME TO CANADIANS
Canada

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) is the Government of Canada's national housing agency. We help Canadians gain access to a wide choice of quality, affordable homes.

Our mortgage loan insurance program has helped many Canadians realize their dream of owning a home. We provide financial assistance to help Canadians most in need to gain access to safe, affordable housing. Through our research, we encourage innovation in housing design and technology, community planning, housing choice and finance. We also work in partnership with industry and other Team Canada members to sell Canadian products and expertise in foreign markets, thereby creating jobs for Canadians here at home.

We offer a wide variety of information products to consumers and the housing industry to help them make informed purchasing and business decisions. With Canada's most comprehensive selection of information about housing and homes, we are Canada's largest publisher of housing information.

In everything that we do, we are helping to improve the quality of life for Canadians in communities across this country. We are helping Canadians live in safe, secure homes. CMHC is home to Canadians.

You can also reach us by phone at 1 800 668-2642
(outside Canada call 613 748-2003)
By fax at 1 800 245-9274
(outside Canada 613 748-2016)

To reach us online, visit our home page at www.cmhc-schl.gc.ca

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.

STRATEGIES FOR REDUCING BUILDING ENERGY USE VIA INNOVATIVE BUILDING ENVELOPE TECHNOLOGIES

FINAL REPORT

October 2003

Prepared for

**Housing Technology Group
Policy and Research Division
Canada Mortgage and Housing Corporation
Ottawa, ON**

Prepared by

**Enermodal Engineering Limited
650 Riverbend Drive
Kitchener, ON N2K 3S2
tel: 519-743-8777
fax: 519-743-8778
e-mail: office@enermodal.com
web site: www.enermodal.com**

in association with

**Halsall Associates Limited
Greenwin Property Management**



ABSTRACT:

A research project was undertaken to evaluate the opportunities to reduce, recover and generate energy at the building envelope in existing multi-unit residential buildings. The research was conducted by a multi-disciplinary team of engineers, architects, building envelope consultants and representatives of the property management industry. The project reviewed new and emerging building envelope technologies that could help to reduce energy consumption in existing buildings, primarily based on experiences in European apartment buildings. Building integrated photovoltaics, solar water heating, solar air heating, insulation and window retrofits and double façade technologies were included in the review. For the most part, it was found that the current economics and risk associated with many of the available technologies can undermine the attractiveness of such technologies for property owners and managers. Two technologies (solar air heating and enclosing balconies) were found to offer attractive energy savings especially if the technologies are incorporated into a larger renovation project and the benefits derived from offsetting future repair costs are considered.

DISCLAIMER

The report contained herein was prepared for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the author and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

Table of Contents

Abstract.....	i
Disclaimer.....	ii
Executive Summary.....	1
1.0 Introduction	2
2.0 Strategies for Envelope Retrofit	3
2.1 Building Envelope Relevant Problems in Canadian Apartments	3
2.2 Develop of Envelope Retrofit Strategies	5
3.0 Detailed Assessment of Strategies	12
3.1 Methodology	12
3.2 Solarwall System	12
3.3 Enclosed Balconies	15
4.0 Conclusions	20
5.0 References	21
Appendix A RETScreen Analysis of PV and SDHW Systems	22

EXECUTIVE SUMMARY

A research project was undertaken to evaluate the opportunities to reduce, recover and generate energy at the building envelope in existing multi-unit residential buildings. The research was conducted by a multi-disciplinary team of engineers, architects, building envelope consultants and representatives of the property management sector. This approach was taken to ensure that any of the technologies proposed would be realistic from as many points of view as possible. The project reviewed new and emerging technologies that could help to reduce energy consumption in existing buildings, primarily based on experiences in European apartment buildings. Building integrated photovoltaics, solar water heating, solar air heating, insulation and window retrofits and double façade technologies were included in the review.

Based on a preliminary assessment of the technologies by the project team, two technologies (solar air heating and enclosing balconies) were selected for a more detailed evaluation based on their ability to not only reduce building energy use but also to address other building performance problems. In the case of solar air heating, this technology was deemed to be potentially attractive to building owners as it reduces energy use associated with tempering corridor ventilation air and can be easily integrated into building envelope renewal work. The technology can also be used to recover heat from exhaust air systems and from exterior wall heat losses. Enclosed balconies were considered viable as they can reduce space heating energy requirements, increase usable space within apartments and can offset balcony and railing repair and replacement costs.

The technologies were assessed using a computer model of an actual multi-unit residential building located in Toronto, Ontario, Canada. The model was used to evaluate the impact of the technologies on building space heating energy use. For the solar air heating system, it was found that the simple payback of the technology was less than 10 years. The payback was reduced to less than 5 years if the technology was implemented as part of a larger building recladding project. In the case of the installation of window and panel systems to enclose balconies, depending on the thermal performance of the window and panel systems used and whether or not the balcony area would become part of the heated space, the payback ranged from 10 to more than 40 years when offset balcony repair costs were considered.

For the most part, it was found that the current economics and risk associated with many of the available technologies can undermine their attractiveness to property owners and managers. For energy reducing, recovery or generation technologies to be attractive to property owners of existing multi-unit residential buildings, the technologies must be relatively risk-free, have short (under 5 years) payback periods, be easily (and cost-effectively) implemented as a part of a larger building repair or renewal projects, be able to address other building performance problems or reduce operational expenses associated with building repair and renewal.

RÉSUMÉ

Une recherche, visant à évaluer le potentiel d'exploiter l'enveloppe des collectifs d'habitation pour réduire, récupérer et produire de l'énergie, a été menée par une équipe multidisciplinaire d'ingénieurs, d'architectes, de consultants spécialistes de l'enveloppe du bâtiment et de représentants du secteur de la gestion immobilière. Cette démarche a été adoptée pour que toute technologie proposée soit réaliste d'autant de points de vue que possible. La recherche touchait les technologies nouvelles ou naissantes qui pourraient contribuer à réduire la consommation énergétique des bâtiments existants, surtout d'après la situation des immeubles d'appartements en Europe. La recherche a envisagé les panneaux photovoltaïques intégrés au bâtiment, le chauffage solaire de l'eau, le chauffage solaire de l'air, l'isolation thermique et les mesures de rattrapage des fenêtres et les doubles façades.

Après avoir effectué une étude préliminaire des technologies, l'équipe de recherche a choisi de soumettre deux technologies (chauffage solaire de l'air et encloisonnement des balcons) à une évaluation approfondie, fondée non seulement sur leur capacité à réduire la consommation énergétique du bâtiment, mais aussi à régler d'autres ennuis de performance. La technologie du chauffage solaire de l'air a été jugée susceptible d'intéresser les propriétaires immobiliers puisqu'elle permet de réduire la consommation d'énergie liée au préchauffage de l'air de ventilation des corridors et peut facilement s'inscrire dans les travaux de réfection de l'enveloppe des bâtiments. La technologie peut également servir à récupérer la chaleur des installations d'extraction et les déperditions de chaleur des murs extérieurs. L'encloisonnement des balcons a été considéré comme une mesure viable puisqu'il permet de réduire les besoins de chauffage des locaux, d'accroître l'aire utilisable des appartements et de compenser les coûts de réparation ou de remplacement des balcons et garde-corps.

Les technologies ont été soumises à l'évaluation du modèle informatique d'un véritable collectif d'habitation situé à Toronto, en Ontario. Le modèle a servi à évaluer l'incidence des technologies sur la consommation d'énergie de chauffage des locaux. On a découvert que le délai de récupération simple de l'installation solaire de chauffage de l'air était inférieur à 10 ans. Il passait à moins de 5 ans si la technologie était appliquée dans le cadre de la mise en place d'un nouveau parement. Quant à la pose de fenêtres et de panneaux d'encloisonnement des balcons, compte tenu de la performance thermique des systèmes de fenêtres et panneaux ainsi que de la possibilité de chauffer les balcons encloisonnés, le délai de récupération fluctuait entre 10 et plus de 40 ans lorsqu'on tenait compte du coût de réparation des balcons.

On a essentiellement découvert que le profil économique actuel et les risques que posent bon nombre des technologies disponibles minent l'intérêt des propriétaires et gestionnaires immobiliers. Pour susciter l'intérêt des propriétaires des collectifs d'habitation, les technologies de réduction, de récupération ou de production d'énergie doivent comporter peu de risques, être assorties d'un délai de récupération court (moins de 5 ans), se mettre en place facilement (et de façon efficiente) dans le cadre d'importants travaux de réparation ou de réfection du bâtiment, être en mesure de régler d'autres

ennuis de performance du bâtiment ou de réduire les dépenses d'utilisation liées à la réparation ou à la réfection du bâtiment.



National Office

Bureau national

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

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 CI-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 () _____

1.0 INTRODUCTION

The goal of this project is to assess strategies for retrofitting building envelopes of multi-unit residential buildings with products or systems that can reduce overall building energy consumption by reducing, re-using or generating energy at the building envelope. There are over three million apartment units in Canada most of which are over 20 years old. As older apartment buildings tend to be leaky and poorly insulated, space heating energy consumption can be high, building envelope problems become more frequent and occupant complaints concerning indoor air quality and comfort are common. Thus, the emphasis of the project is to identify and assess those strategies that can not only save energy but also solve other building problems by reducing maintenance and repair costs or improving occupant comfort or indoor air quality. Such solutions should be more attractive to property owners and managers, hence more likely to be implemented, than measures that address energy savings alone.

The project had three objectives:

- Identify promising envelope systems or measures for reducing energy use while improving other aspects of building performance such as durability and the indoor environment
- Assess the cost, performance and ease of retrofit of the selected systems
- Recommend where these systems are best suited and identify a system for further study.

The project was carried out by a project team consisting of energy engineers, property managers and building envelope consultants. The interdisciplinary team approach was chosen so that the project would focus on realistic, cost-effective technologies.

2.0 STRATEGIES FOR ENVELOPE RETROFIT

A preliminary workshop was held to review the current condition of the apartment building stock and to identify typical performance problems (see Section 2.1). The workshop included representatives from the property management, building envelope and energy-environmental engineering communities. Through the development of a list of typical building problems it was hoped that innovative energy saving, reducing or generating technologies could be proposed that would solve a problem while reducing energy consumption. Solving a problem would be the primary motivation for the property manager/owner to undertake the work. It was also recognized that the cost effectiveness (hence the likelihood of being implemented) of the energy saving, reducing or generating technologies would be greatly improved if they could offset an otherwise energy-neutral repair cost.

The second purpose was to identify alternative energy strategies that could be retrofit to high-rise apartment buildings. Descriptions and preliminary assessments of the strategies discussed during the workshop are presented in Section 2.2. This assessment of the strategies also included a discussion of the experience of European retrofit projects as discussed in an International Energy Agency report [1]. This report examined energy efficiency retrofits in over twenty retrofit multi-unit residential buildings (MURBs).

2.1 Building Envelope Relevant Problems in Canadian Apartment Buildings

There are over three million apartment units in Canada most of which are over 20 years old. While these buildings provide suitable habitat for a large number of Canadians, as a result of their age they are expected to experience ever increasing maintenance and repair costs, poor indoor air quality and thermal comfort and high energy costs.

With respect to the building envelope, aging balcony slabs and railings and deteriorating masonry façades represent the two most costly forms of repair work. Over time, concrete balconies deteriorate due to water penetration that can delaminate the concrete and corrode reinforcing bars. Steel and concrete railings can also deteriorate with time or may no longer meet current building code requirements with respect to their ability to resist lateral loading and the spacing of guards. Members of the project team reported that repairs to balconies often represent the largest single apartment building repair and maintenance cost.

Poor flashing design, deteriorated mortar joints and poor water shedding details can cause moisture migration into exterior walls. Moisture saturated masonry, coupled with an adequate number of freeze-thaw cycles, can quickly deteriorate. If left untreated, the bricks could eventually fall off the building. For many building owners, the easiest method of dealing with this problem is to clad over the brick with aluminum or steel siding. In some cases the entire building is re-clad whereas in other cases only the upper floors. Figure 1 shows a building where cladding has been used to cover and protect masonry facades.



Figure 1: Aluminum Cladding over a Brick Veneer Apartment

Older apartment buildings also typically lack continuous air barrier systems. Air movement within such buildings tends to be dominated by stack and wind pressures. Cold outdoor air tends to leak into lower windward suites and warm moist air is driven out through the envelope of leeward suites located on the upper floors. The result is that lower floor suites are cold and drafty and the upper floor suites are hot and stuffy. Such interzonal air movement is largely responsible for occupant complaints concerning the transfer of cooking odors and cigarette smoke between apartments and their inability to control their indoor environment (temperature and humidity).

CMHC supported studies of high-rise rental and condominium repair needs in the Toronto area [2] [3] show that building envelope and structural (parking garage and balconies) repairs can represent a significant proportion (as high as 27% and 21% respectively) of total annual building repair expenditures.

The standard corridor make-up air system installed in most MURBs does a poor job of providing outdoor air to the occupants. Much of the make-up air goes out the elevator shaft or garbage chute rather than into the suites [4]. Ventilation in apartment buildings tends to happen more by accident than design resulting in high energy loss, occupant discomfort and indoor air quality conditions that can damage building envelope facades, interstitial components and interior finishes.

The cost of space heating can be high in MURBs because of low insulation levels and the preference for electric resistance heating at the time most of the apartment building stock in Canada was constructed. It is estimated that approximately 50% of apartment buildings

in Canada are electrically heated. The average total energy consumption of Canadian apartment buildings is 279 kWh per square metre of floor area [5] or approximately \$1000 per apartment if electrically heated.

An energy saving, recovery or generation technology that could address all, or one, of the aforementioned generic MURB performance issues would have the most chance of being considered by building owners and managers.

2.2 Development of Envelope Retrofit Strategies

Improved Wall and Roof Insulation

The most obvious strategy for reducing envelope heat loss is to add insulation to the walls or roof. It is, however, difficult and expensive to add insulation to existing buildings. In one recently completed building envelope retrofit in Toronto (Figure 2) that involved the application of an exterior insulation and finish system over a fired masonry wall, the costs were approximately \$235/m² and had a payback well beyond what property owners would consider economically attractive (95 years). The retrofit was done primarily to address water infiltration, masonry deterioration, building aesthetics and occupant comfort problems. It should be noted that the application of uninsulated steel siding would have cost \$100/m², thus the incremental cost of the EIFS approach was \$135/m².

Several European apartment retrofits included the addition of insulation on external walls, interior walls, or injected into the wall cavity. These insulation retrofits were relatively expensive and were most cost-effective when coupled with other envelope work, such as façade renewal (new bricks or curtainwall system). In some cases, the insulation retrofit was combined with heating/cooling system adjustment to take advantage of reduced heating and cooling loads. The retrofit of additional insulation was not the focus of this study, but could be included as part of an alternative energy retrofit where it would improve the system cost effectiveness.



Figure 2: Application of an EIFS System over a Masonry Wall

Window Retrofits

There are several window retrofit strategies including full replacement with high performance units (low-emissivity coatings, inert gas fillings, insulated frames and edge spacers), installing an additional pane to an existing window, and installing ventilating windows. Additional savings can be achieved when window work is coupled with air sealing around the window opening. High-performance window retrofits cost approximately \$300/m² and offer savings of up to \$10/m². Because of the high cost of window replacement, this measure is not cost effective unless the window is being changed for other reasons (broken window/seal, high maintenance needs, failed operating mechanisms or the desire to increase property value).

Sunspaces/Atria

There are several ways that sunspaces and atria can be retrofit to high-rise residential buildings. A common practice is to enclose existing balconies with window and panel systems to create a sunroom. Figure 3 shows a building where most of the balconies have been enclosed. This buffer space can reduce envelope and balcony heat loss and provide passive solar heating. Vents and/or operable windows can allow for control of ventilation air and rejection of excess summer solar gains.

In European projects, balconies were enclosed to protect the building envelope from the elements, which reduced balcony maintenance costs and reduced space heating costs. In some cases, a enclosed balcony was used to capture solar gains for preheating of ventilation air. Other benefits of enclosed balconies in the European case studies were increased tenant comfort and reduced noise.

The harsh Canadian climate results in high maintenance costs for balconies and railings. Glazing-in the balcony can eliminate these costs and reduce heating costs by providing an extra insulating layer to the building. The envelope around balconies is an area of high heat transfer. Concrete balconies act as a fin transferring interior heat to the outdoors. Sliding (patio) and swinging doors are generally leaky and poorly insulated. The knee wall below the windows overlooking the balcony is also often poorly insulated.

There are several potential strategies for creating sunspaces from balconies. In the simplest case, single-enclosed windows could be added to create a buffer space that protects the balcony from the elements. Provided this space isn't heated, energy could be saved by using the space to preheat ventilation air and to reduce heat loss through the existing apartment wall. It is important to note that the building occupants would have to keep the doors between the balcony space and the interior apartment closed during the heating season to avoid accidental heating of these nominally insulated spaces. At the other extreme, the sunspace can be created using high-performance window and panel system. In this case, the sunspace could be fully heated (to provide additional living area) and the total building heat loss could be reduced.



Figure 3: Balconies Enclosed to Create a Sunspace

Double-Facade Envelopes

A recent building innovation has been the concept of a double façade envelope. Double facades have been constructed covering the original outer façade with an outer glazing system. An interstitial air space is provided between the original envelope and the glazing. This space serves as a buffer zone and, in some cases, an air distribution channel. By opening and closing windows and vents, solar heated air can be directed into the building in the winter and rejected in the summer. This concept has been used in many European buildings and was recently applied to the Telus Building in Vancouver, British Columbia. The main question with this concept is its suitability for residential buildings (smoke and fire control, window operability and noise concerns) and in locations with high sensible and latent cooling loads.

Although several commercial buildings have used double façade envelopes, there are many barriers to their application in MURBs. MURBs differ from office buildings in that most windows are operable and are used to provide supplemental ventilation and free cooling. If the double façade covers operable windows, there is the potential for the transport of smoke, odours and noise between suites. There is also a concern that fire and smoke could propagate throughout a building using the double façade channel. These concerns require further consideration and would have to be addressed to facilitate the application of double façade technologies in multi-unit residential buildings.

A solution to the transfer of noise and smoke could be to compartmentalize the system to each suite. This modification, in effect, reduces the system to the enclosed-in balcony strategy where balcony areas represent a large proportion of the exterior wall area.

Building Integrated Photovoltaics (BIPV)

Photovoltaics (PV) modules can serve as the outer skin of the building. The PV module can replace the spandrel glass or, if made transparent, the vision glass in a curtain wall system. The PV system provides a durable envelope that produces electricity and heat if ventilation air is drawn through the backside of the system. Retrofitting this system can not only address building envelope deterioration problems but also extend the building life by turning a “tired” looking building into a “high-tech” all-glass building. Other strategies include using PV as a window shading device and as a partial screen for atria. The primary challenge of BIPV systems is their high capital cost and relatively unknown lifecycle maintenance and replacement costs. BIPV systems that are coupled to the electricity grid can be relatively simple in that battery storage systems are not required and electricity generated by the building can be credited against utility bills.

In a few European projects, photovoltaic panels were integrated into south facing walls and roofs to offset building electrical loads. The panels were located on racks on the roof, or integrated into building envelope members. This technology was very expensive and a full system required additional electrical equipment (batteries, inverters, and grid connections).

A pre-feasibility study on the potential for PV was performed using the RETScreen assessment tool [6]. The cost of the PV modules was estimated to be \$6/Watt. Including inverters, and installation, the total installed cost was estimated at \$12/watt. A vertically mounted system could provide a credit of up to \$150/m² if the building cladding were in need of repair or replacement. According to the RETScreen analysis (see Appendix A), over a 30 year time period, the levelized cost for a BIPV system is approximately 50¢/kWh, which is much higher than the current Canadian market rate for electricity of approximately 10¢/kWh. Building integrated photovoltaics, at the present time, is not a cost-effective building retrofit measure.

Solar Ventilation Air Heating

Ventilation air heating can be a significant heating load in multi-unit residential buildings. A recent CMHC study [7] found that the cost of heating corridor air can range from \$5,000 to \$20,000 annually (or \$2.50 per L/s) in the five Winnipeg buildings studied. The application of conventional heat recovery systems to reduce tempering costs is not always practical because the point where supply air is drawn into the building is not always the same location where exhaust air is vented.

The Solarwall™ technology is a cladding system that can preheat ventilation air. Metal panels, installed over a selected wall area, are used to form an air intake system that warms the air (by solar gains on the panels) as it moves up behind the panels into the building's ventilation air delivery system. While the primary tempering is achieved by direct solar gains on the panels, it is also possible to connect individual suite exhausts to the system to recover heat from the exhaust air.

The system has been successfully applied to an apartment building in Windsor, Ontario, as the world's tallest solar heating system (see Figure 4). Solarwall™ can be a cost effective alternative cladding system particularly when installed as a part of an overall building envelope rehabilitation project.



Figure 4: Solarwall™ Installed on an Apartment Building

Solarwall-type systems show promise because the panels can be used to re-clad damaged envelope systems, serve as an insulating airspace (including air sealing), and can be used for winter make-up air heating. When providing these multiple purposes, there is potential for this system to be cost-effective. The technology is best suited to apartment building end walls where the walls are free of windows and doors.

Solar Domestic Water Heaters

Solar domestic hot water collectors can be installed on roofs or integrated into south-facing walls. In Europe, many apartment buildings are low rise with pitched roofs. This arrangement facilitates integration of the collectors into the roof. Building-integrated solar collectors are most cost-effective when the roof requires replacement, particularly when a flat roof is rebuilt as a pitched roof to lower maintenance costs.

Most Canadian mid- and high-rise apartment buildings have flat roofs. These buildings do not lend themselves to conversion to pitched roofs, thus in most cases a support rack is required for the solar installation.

A pre-feasibility on the potential for solar DHW systems was undertaken using the RETScreen assessment tool (see Appendix A). The installed cost of a enclosed solar DHW system was estimated at \$400 per square metre. At this cost, the payback of a rack-mounted solar DHW system was approximately 20 years. Thus, solar DHW does not appear to be a promising retrofit technology for apartment buildings given current technology costs and energy prices.

Summary

At the conclusion of the workshop, two strategies were selected for further study: balcony conversion to sunspace and solar preheating of ventilation air (e.g.; Solarwall™). These technologies were deemed to be the most attractive to building owners and managers as they can be relatively cost-effective, particularly as a part of work that would otherwise have to be done to address building performance problems. BIPV and solar water heating were deemed too expensive to be of interest to apartment building owners. The cost and performance of these technologies are expected to improve over time and may be cost effective in the future. Double-façade envelopes present many challenges for apartment buildings in terms of noise and smoke control and the inability of tenants to access the outdoors by opening windows. It would appear that compartmentalization of this strategy is required for the MURB market, which is in essence the enclosed-in balcony concept.

3.0 DETAILED ASSESSMENT OF STRATEGIES

3.1 Methodology

Based on the workshop and the analysis of the various retrofit options described in Section 2, two envelope retrofit strategies emerged as the most promising to reduce and recover energy in MURBs: (1) Solarwall™-type air pre-heat system, and (2) enclosed balconies. This Section of the report assesses capital costs and energy savings associated with these strategies. To assess the strategies, specifications from an existing 1965-era 16-storey, 187-suite rental apartment building in downtown Toronto were used (Figure 5). The building represents a “typical” Canadian apartment building to which these strategies could be applied.



Figure 5: Photograph of Study Building (on left)

3.2 Solarwall™ System

Apartment buildings are typically ventilated by a corridor air system and either in-suite or central exhaust fans that serve kitchen and bathroom areas. Building codes requirements for apartment ventilation vary most defer to ASHRAE Standard 62-2001 “Ventilation for Acceptable Indoor Air Quality”. For the case study building, it was assumed that 3,965 L/s (8,400 cfm) is introduced into the building. Heating of this outdoor air represents a heating energy load of approximately 1460 GJ per year, or about \$11,500. (based on heating with natural gas at 67% seasonal efficiency and a cost of \$0.25/m³).

Solar Air Preheat Configuration

The Solarwall™ consists of a dark coloured perforated panel installed on the south wall of a building. The panel is mounted approximately 200 mm off the wall to create a

channel for airflow. Ventilation air is pulled through the holes in the panel, along the channel and delivered to the building by the existing corridor air unit. When the sun shines on the panel, it becomes hot and transfers heat to the ventilation air.

The Solarwall™ offers two other important benefits. The Solarwall™ can serve as a part of new over-cladding system for the building, installed to address building envelope deterioration problems and to improve building aesthetics. Second, the Solarwall™ recovers approximately half the adjacent wall heat loss that would otherwise be lost from the building by capturing the wall heat loss in the incoming ventilation air.

The Solarwall™ is typically sized at between 40 and 80 L/s of ventilation air per square metre of panel area. At the low flows, the system will deliver warmer air but will operate at a lower efficiency. At high flow rates per unit area, the collection efficiency is high and the temperature rise is low. The case study building contains a continuous opaque wall area on the south side ideally suited to Solarwall™ retrofit. The area is brick through all 17 stories, 5 metres wide, and is free from window penetrations or balcony obstructions. The total wall area is 224 square metres, oriented 15° east of due south. For the required ventilation rate, the Solarwall™ area should be between 112 and 224 square metres.

Energy Savings

Energy calculations for the Solarwall™ system were calculated using Natural Resources Canada's SWIFT software [7]. This software was specifically designed to determine the performance of the Solarwall™ system and calculates energy savings on an hourly basis using TMY weather data. Three separate simulations were performed: (1) the Solarwall™ covers the total available wall area (45 metres long X 5 metres wide), (2) the Solarwall™ covers 75% of the available wall area (34 metres long X 5 metres wide) and (3) the Solarwall™ covers 50% of the available wall area (22.5 metres long X 5 metres wide). The results of the simulations are summarized in Table 1. For all cases, the maximum useful supply temperature was taken to be 22°C. If the air was delivered at a warmer temperature, it would cause the apartment corridors to overheat. Energy cost savings are calculated on the basis of both displaced natural gas heating (at 67% seasonal efficiency) and electric resistance heating.

Table 1: Performance of Solarwall™ System

Solarwall™ Size	100% Wall Coverage	75 % Wall Coverage	50% Wall Coverage
Total Area (m²)	224	168	112
Annual Solar Energy Collected (GJ)	306.6	260.6	200.4
Solar Energy Incident While Operating (GJ)	510.7	399.2	276.2
Ventilation Heating Load (GJ)	1460	1460	1460
Ventilation Load Offset by Solarwall™ (%)	21%	18%	14%
Energy Savings, if displacing Natural Gas (@ 25¢/m³)	\$3,620	\$3,020	\$2,280
Energy Savings, if displacing Electricity (@ 7¢/kWh)	\$7,140	\$5,955	\$4,490

Economic Analysis

A design concept for the system was developed and priced. The costing was performed based on budget prices supplied by equipment manufacturers. Estimated material and installation costs for the modeled building appear in Table 2.

Table 2: Solarwall™ Equipment and Installation Costs

Interconnection at existing fan and ductwork	\$8,000
Ducting from Solarwall™ to interconnection point (15 m)	\$8,000
Material Cost (\$/m²)	\$ 86.00
Installation Cost (\$/m²)	\$ 91.50

Table 3 presents the economic results assuming that the no building recladding is required. In Table 4, the Solarwall™ cost effectiveness is presented assuming that the brick veneer must be repaired or re-clad with steel siding. Typical re-cladding projects in the Toronto market are approximately \$150/m².

Tables 3 and 4 show that the cost effectiveness of retrofitting a Solarwall™ system on an apartment building is relatively insensitive to system size. The economics of this retrofit option are favoured by high energy prices and by implementing the retrofit as an integral part of a buildings re-cladding renovation project. The payback period is in the range from 3 to 8 years assuming recladding is necessary.

Table 3: Solarwall™ Economic Analysis Assuming No Re-Cladding

Solarwall™ Size	100% Wall Coverage	75 % Wall Coverage	50% Wall Coverage
Fixed Connection Point Cost	\$16,000	\$16,000	\$16,000
Material Cost	\$19,200	\$14,400	\$9,600
Installation Cost	\$20,400	\$15,300	\$10,200
Total Cost	\$55,600	\$45,700	\$35,800
Annual Energy Savings (if natural gas heated)	\$3,620	\$3,020	\$2,280
Simple Payback, (natural gas @ 25¢/m³)	15.4 years	15.1 years	15.7 years
Annual Energy Savings (if heated by electricity)	\$7,140	\$5,955	\$4,490
Simple Payback (electricity @ 7¢/kWh)	7.8 years	7.7 years	8.0 years

Table 4: Solarwall™ Economic Analysis Assuming Re-Cladding is Required

Solarwall™ Size	100% Wall Coverage	75 % Wall Coverage	50% Wall Coverage
Total Cost (from Table 3)	\$55,600	\$45,700	\$35,800
Avoided Re-Cladding Costs	\$33,600	\$25,200	\$16,800
Annual Energy Savings (if natural gas heated)	\$3,620	\$3,020	\$2,280
Simple Payback, (natural gas @ 25¢/m³)	6.0 years	6.8 years	8.3 years
Annual Energy Savings (if heated by electricity)	\$7,140	\$5,955	\$4,490
Simple Payback (electricity @ 7¢/kWh)	3.1 years	3.4 years	4.2 years

3.3 Enclosed Balconies

Balconies represent one of the most expensive building envelope maintenance items. A retrofit measure that has been employed to reduce balcony maintenance costs is to enclose balconies with a window system while maintaining the separation between the balcony and the indoor space behind it. In certain configurations and situations, the

enclosed balcony can reduce building energy consumption as well, by (1) facilitating passive solar heating, and (2) reducing envelope heat transfer. Using the case study building as an example, a number of energy modeling scenarios were completed to investigate which configurations show the greatest potential for reducing building energy use.

Balcony Configuration

In multi-unit residential buildings, floor plans are generally identical. Since balconies are generally “stacked” on top of one another, balconies can be enclosed with window systems by spanning between the balcony slab edges floor to floor. Balconies generally appear in one of two configurations: cantilevered (balconies protrude from the main exterior wall of the building) and recessed (balconies contained within the main exterior wall). The case study building contains 187 balconies in a protruding configuration, although both cases were considered in this study. In both cases, the balcony area is 4.9 metres wide x 1.3 metres deep, and slab-to-slab height is 2.75 metres. In the protruding balcony case, the total exterior wall area per suite is 13.4 square metres of which 75% is window and sliding glass door. The exterior wall area for the recessed balcony case is 20.5 square metres per suite. For each of the protruding and recessed balcony configurations, the following scenarios were modeled:

1. Base case – The balcony is not enclosed. The balcony windows are assumed to be double-enclosed units with thermally broken aluminium frames.
2. Sunspace – The balcony is enclosed with a single pane of glass; the balcony is not intended for winter use. Door to balcony is closed during heating season.
3. Winterized – The balcony is enclosed by a double-enclosed window system; the balcony may be heated during the winter. Door to balcony is open all year.
4. Winterized high-performance – The balcony is enclosed by a double-enclosed window system with low-e coating and argon gas fill for maximum winter performance. Door to balcony is open all year.

Energy Modeling Results

Scenarios were modeled using DOE 2.1 building energy modeling software. The building was heated with electric resistance baseboard units and cooled with a packaged through-the-wall air conditioning unit. Energy costs are based on an electricity cost of 7¢/kWh. The results appear in Tables 5 and 6.

Table 5: Energy Savings for Enclosing Cantilevered Balconies

Scenario	Heating Energy (kWh)	Cooling Energy (kWh)	Total Energy (kWh)	Annual Energy Savings per Suite
North-Facing Suite				
Base Case	6723	587	7310	--
Sunspace	6097	578	6675	\$ 44
Winterized	9096	841	9937	(\$ 184)
Hi-Perf Winterized	8235	585	8820	(\$ 106)
South-Facing Suite				
Base Case	3921	974	4895	--
Sunspace	3496	956	4452	\$ 31
Winterized	4962	2016	6978	(\$ 146)
Hi-Perf Winterized	4990	1250	6240	(\$ 94)
Total Building (187 Balconies)				
Base Case	989,892	145,173	1,135,065	--
Sunspace	892,149	142,662	1,034,811	\$ 7,000
Winterized	1,307,394	265,701	1,573,095	\$ (30,700)
Hi-Perf Winterized	1,229,925	170,655	1,400,580	\$ (18,600)

Table 6: Energy Savings for Enclosing Recessed Balconies

Scenario	Heating Energy (kWh)	Cooling Energy (kWh)	Total Energy (kWh)	Annual Energy Savings per Suite
North-Facing Suite				
Base Case	7605	572	8177	--
Sunspace	6792	578	7370	\$ 56
Winterized	7155	659	7814	\$ 25
Hi-Perf Winterized	6541	507	7048	\$ 79
South-Facing Suite				
Base Case	4632	944	5576	--
Sunspace	4025	1052	5077	\$ 35
Winterized	4039	1235	5274	\$ 21
Hi-Perf Winterized	4043	896	4939	\$ 45
Total Building (187 Balconies)				
Base Case	1,138,041	140,988	1,279,029	--
Sunspace	1,005,981	151,590	1,157,571	\$ 8,500
Winterized	1,041,042	176,142	1,217,184	\$ 4,300
Hi-Perf Winterized	984,312	130,479	1,114,791	\$ 11,500

Economic Analysis

A design concept for the balcony glazing system was developed and priced. The system costs were estimated by a building envelope consultant based on Toronto area prices. The economic analysis was performed for both cantilevered and recessed balconies.

Table 7: Base Costs for Enclosing Balconies

Scenario	Unit Price (\$/m ²)	Total Building Cost – Cantilevered Balconies	Total Building Cost – Recessed Balconies
Sunspace	\$ 240 to \$ 260	\$ 850,000	\$ 550,000
Winterized	\$ 280 to \$ 300	\$ 1,000,000	\$ 650,000
Hi-Perf Winterized	\$ 310 to \$ 330	\$ 1,100,000	\$ 750,000

Based on the information tables above, it is not economically feasible to enclose balconies based on energy savings alone. For cantilevered balconies, the increased surface area results in an overall increase in space heating energy use. However, there are additional economic benefits to this measure that should be considered. First, the cost and risk of future concrete and balcony railing repairs is reduced or eliminated, because balconies are no longer exposed to the elements (although there would be maintenance and repairs associated with the enclosing window system). Typical repair work for a building of this size can be in hundreds of thousands of dollars range. Secondly, the cost of periodic balcony maintenance is avoided. Such repairs typically include application of a membrane to the concrete and removal, repair and repainting of balcony railings. This represents an avoided cost of approximately \$120,000 every 15 to 20 years for the case study building. Second, enclosing the balcony eliminates the need to repair or replace the windows that look onto the balcony. The typical cost of apartment window replacement is \$200/m². The economics of this situation is given in Table 8 for recessed balconies.

Table 8: Economics of Glazing Recessed Balconies – Total Building

	Recessed Balconies		
	Sunspace	Winterized	Hi-Perf Winterized
Annual Energy Savings	\$8,500/year	\$4,300/year	\$11,500/year
Glazing Balconies	\$550,000	\$ 650,000	\$ 750,000
Reduced Balcony Maintenance	(\$120,000)	(\$ 120,000)	(\$ 120,000)
Reduced Window Replacement	(\$ 340,000)	(\$ 340,000)	(\$ 340,000)
Net Cost	\$90,000	\$ 190,000	\$290,00
Simple Payback	10.5 years	44 years	25 years

Table 8 shows paybacks of over 10 years. Although the payback periods are long, enclosing the balconies increases the usable floor area by 6.3 square metres. All three strategies provide more living space with lower energy bills. It should be noted that the windows in the sunspace may have to be replaced after 30 years of service.

4.0 CONCLUSIONS

This report examined the feasibility of retrofitting strategies to reduce, recover or generate energy at the building envelope of multi-unit residential buildings. Because the cost of retrofitting energy efficiency measures can be expensive, the emphasis of this report was to examine strategies that could be implemented as a part of larger building renewal projects and that could also offset long-term maintenance and repair costs. Older apartment buildings often face high maintenance costs to repair balconies, balcony railings, exterior façades and to replace windows. Technologies that could reduce the cost or frequency of such repairs, while reducing energy costs, would be more attractive to building owners and more likely to be implemented.

Most of the building envelope strategies reviewed were found to be too expensive or involve a high degree of risk to appeal to apartment building owners. The most promising strategies appear to be installing a solar air heating system (e.g.; Solarwall™) to preheat corridor ventilation air when the brick façade is in need of replacement and enclosing balconies with window systems when the balconies and windows are in need of repair.

A Solarwall™ system costs approximately \$250 per square metre and can save \$16 to \$24 per square metre in energy costs. The payback period is 10 to 15 years. However, by displacing the need to repair portions of masonry facades, the incremental cost is under \$100 per square metre. The payback on this investment is between 3 and 8 years.

Three strategies for enclosing balconies were studied: sunspace (single enclosed, seasonal use), winterized (double enclosed), high performance (double enclosed low-e argon). Two balcony arrangements were investigated: protruding balconies and recessed balconies. Enclosing protruding balconies tended to result in increased space heating energy use because of the increased envelope area. Recessed balconies were always a net energy saver.

The cost to enclose balconies was \$240 to \$330 per square metre depending on the type of glazing used. However, this work will result in repair and maintenance cost savings associated with the elimination of balcony repairs and window replacements. The payback on the incremental cost is 10 years for the sunspace arrangement and 25 years for the high-performance window arrangement. Although the payback for the latter arrangement is long, it increases the usable floor area of the apartment and provides a desirable amenity where none existed before.

5.0 REFERENCES

- [1] IEA, 2001. Retrofitting Energy Efficiency in Apartment Buildings, CADDET Analysis Series, International Energy Agency, Sittard, the Netherlands
- [2] Canada Mortgage and Housing Corporation, “High-Rise Apartment Repair Needs Assessment in the Former Cities of Toronto and York”, 1998, Gerald R. Genge Building Consultants Inc.
- [3] Canada Mortgage and Housing Corporation, “Condition Assessment of Condominiums in the Greater Toronto Area”, 2003, Gerald R. Genge Building Consultants Inc.
- [4] Canada Mortgage and Housing Corporation “Field Testing to Characterize Suite Ventilation in Recently Constructed Mid and High-Rise Residential buildings”, Sheltair Scientific Ltd, November 1998.
- [5] Canada Mortgage and Housing Corporation, “Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database”, Research Highlight, 2001, Enermodal Engineering Limited
- [6] NRCan, 2003. RETScreen Pre-Feasibility Software Tool. www.etscreen.net
- [7] Canada Mortgage and Housing Corporation, “Corridor Air Ventilation System Energy Use in Multi-Unit Residential Buildings”, UNIES Ltd, October 1999.
- [8] NRCan, 2000. SWIFT Computer Program for Analysing Solar Air Heating Systems, CANMET, Natural Resources Canada, Ottawa, ON

Appendix A: RETScreen Analyses of PV and SDHW Systems

RETScreen® Energy Model - Photovoltaic Project

Site Conditions		Estimate	Notes/Range
Project name		4 kW PV System	
Project location		Toronto	
Nearest location for weather data	-	Toronto, ON	<i>Complete SR&SL sheet</i>
Latitude of project location	°N	43.7	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m ²	1.44	
Annual average temperature	°C	7.2	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		Siemens/ SM100	<i>See Product Database</i>
Nominal PV module efficiency	%	11.5%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	2.0%	0.0% to 20.0%
Nominal PV array power	kWp	4.00	
PV array area	m ²	34.8	
Power Conditioning			
Average inverter efficiency	%	95%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	3.8	
Inverter capacity	kW (AC)	4.0	
Miscellaneous power conditioning losses	%	10%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m ²	137.1	
Overall PV system efficiency	%	9.5%	
Renewable energy collected	MWh	5.019	
Renewable energy delivered	MWh	4.768	
	kWh	4768	
Excess RE available	MWh	0.000	<i>Complete Cost Analysis sheet</i>

RETScreen® Financial Summary - Photovoltaic Project

Annual Energy Balance					
Project name	4 kW PV System				
Project location	Toronto	Nominal PV array power	kWp	4.00	
Renewable energy delivered	MWh	4.768	GHG analysis sheet used?	yes/no	No
Firm RE capacity	kW	-			
Application type	On-grid				

Financial Parameters					
Avoided cost of energy	\$/kWh	0.080	Debt ratio	%	0.0%
RE production credit	\$/kWh	-			
			Income tax analysis?	yes/no	No
Energy cost escalation rate	%	2.5%			
Inflation	%	2.5%			
Discount rate	%	8.0%			
Project life	yr	30			

Project Costs and Savings					
Initial Costs			Annual Costs and Debt		
Feasibility study	1.5%	\$ 670	O&M	\$	1
Development	3.3%	\$ 1,510			
Engineering	4.5%	\$ 2,045			
RE equipment	71.3%	\$ 32,200	Annual Costs - Total	\$	1
Balance of equipment	9.5%	\$ 4,278			
Miscellaneous	9.9%	\$ 4,460	Annual Savings or Income		
Initial Costs - Total	100.0%	\$ 45,164	Energy savings/income	\$	381
Incentives/Grants		\$ -	Capacity savings/income	\$	-
			Annual Savings - Total	\$	381
Periodic Costs (Credits)					
	\$	-			
	\$	-			
	\$	-			
End of project life -	\$	-			

Financial Feasibility					
			Calculate RE production cost?	yes/no	No
Pre-tax IRR and ROI	%	-5.0%			
After-tax IRR and ROI	%	-5.0%			
Simple Payback	yr	118.7	Project equity	\$	45,164
Year-to-positive cash flow	yr	more than 30			
Net Present Value - NPV	\$	(39,552)			
Annual Life Cycle Savings	\$	(3,513)			
Profitability Index - PI	-	(0.88)			

RETScreen® Energy Model - Solar Water Heating Project

Site Conditions		Estimate	Notes/Range
Project name		Apartment SWH	
Project location		Toronto, ON	
Nearest location for weather data		Toronto, ON	<u>Complete SR&HLC sheet</u>
Annual solar radiation (tilted surface)	MWh/m ²	1.44	
Annual average temperature	°C	7.2	
Annual average wind speed	m/s	#DIV/0!	
Desired load temperature	°C	60	
Hot water use	L/d	25,041	
Number of months analysed	month	12.0	
Energy demand for months analysed	MWh	532.92	

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	Natural gas	
Heating system seasonal efficiency	%	85%	60% to 300%
Solar Collector			
Collector type	-	Glazed	<u>See Technical Note 1</u>
Solar water heating collector manufacturer		Thermo Dynamics	<u>See Product Database</u>
Solar water heating collector model		G32	
Area per collector	m ²	3.00	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.74	0.50 to 0.90
Fr UL coefficient	(W/m ²)/°C	5.25	3.50 to 6.00
Suggested number of collectors		130	
Number of collectors		80	
Total collector area	m ²	240.0	
Storage			
Ratio of storage capacity to coll. area	L/m ²	37.5	37.5 to 100.0
Storage capacity	L	9,000	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	Yes	
Heat exchanger effectiveness	%	75%	50% to 85%
Suggested pipe diameter	mm	N/A	8 to 25 or PVC 30 to 38
Pipe diameter	mm	38	8 to 25 or PVC 30 to 38
Pumping power per collector area	W/m ²	5	3 to 22, or 0
Piping and solar tank losses	%	5%	1% to 10%
Losses due to snow and/or dirt	%	5%	2% to 10%
Horz. dist. from mech. room to collector	m	20	5 to 20
# of floors from mech. room to collector	-	4	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Pumping energy (electricity)	MWh	2.07	
Specific yield	kWh/m ²	487	
System efficiency	%	34%	
Solar fraction for months analysed	%	22%	
Renewable energy delivered	MWh	116.83	
	GJ	420.6	<u>Complete Cost Analysis sheet</u>

RETScreen® Financial Summary - Solar Water Heating Project

Annual Energy Balance					
Project name		Apartment SWH	Electricity required	MWh	2.1
Project location		Toronto, ON			
Renewable energy delivered	MWh	116.83	GHG analysis sheet used?	yes/no	No
Heating fuel displaced	-	Natural gas			

Financial Parameters					
Avoided cost of heating energy	\$/m³	0.350	Debt ratio	%	0.0%
			Income tax analysis?	yes/no	No
Retail price of electricity	\$/kWh	-			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.0%			
Discount rate	%	8.0%			
Project life	yr	25			

Project Costs and Savings						
Initial Costs				Annual Costs and Debt		
Feasibility study	0.0%	\$	-	O&M	\$	-
Development	0.0%	\$	-	Fuel/Electricity	\$	-
Engineering	0.0%	\$	-			
RE equipment	67.3%	\$	146,137	Annual Costs - Total	\$	-
Balance of system	23.5%	\$	50,955			
Miscellaneous	9.2%	\$	19,949	Annual Savings or Income		
Initial Costs - Total	100.0%	\$	217,040	Heating energy savings/income	\$	5,655
Incentives/Grants		\$	500			
				Annual Savings - Total	\$	5,655
Periodic Costs (Credits)						
Valves and fittings		\$	-			
Pool heat pump compressor		\$	-			
		\$	-			
End of project life -		\$	-			

Financial Feasibility					
Pre-tax IRR and ROI	%	-0.1%			
After-tax IRR and ROI	%	-0.1%			
Simple Payback	yr	38.3	Project equity	\$	217,040
Year-to-positive cash flow	yr	more than 25			
Net Present Value - NPV	\$	(135,663)			
Annual Life Cycle Savings	\$	(12,709)			
Profitability Index - PI	-	(0.63)			

Visit our home page at www.cmhc.ca