Passive Solar Potential In Canada: 1990 - 2010

PREPARED FOR:

Buildings Group R&D Program
CANMET Energy Technology Centre – Ottawa
Energy Sector, Natural Resources Canada
Ottawa, Ontario, Canada, K1A 0E4
DSS Contract No.: 69SZ.23216-8-9043
March 1990

PREPARED BY:

Scanada Consultants Limited
446 Reynolds Street
Oakville, Ontario, L6J 3M4
Tel: 905-842-3633; Fax: 905-842-3638

SCIENTIFIC AUTHORITY:

Mark Riley
Buildings Group R&D Program
CANMET Energy Technology Centre - Ottawa
Energy Sector, Natural Resources Canada
580 Booth Street, 13th Floor,
Ottawa, Ontario, Canada, K1A 0E4

November 12, 2002

CITATION

Parekh, A. and Platts, R.E., Scanada Consultants Limited. *Passive Solar Potential in Canada: 1990 – 2010.* Prepared under DSS contract File No. 69SZ.23216-8-9043. Buildings Group R&D Program, CANMET Energy Technology Centre - Ottawa, Energy Sector, Natural Resources Canada, Ottawa, Ontario, Canada, 1990. (97 pages).

Copies of this report may be obtained through the following:

CANMET Energy Technology Centre
Natural Resources Canada, Energy Sector
580 Booth Street, 13th Floor
Ottawa, Ontario
Canada, K1A 0E4

DISCLAIMER

This report is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada, its ministers, officers, employees, agents, nor Zephyr North make any warranty or representation, expressed or implied, with respect to the use of any information, apparatus, method, process or similar item disclosed in this report, that such use does not infringe on or interfere with the privately owned rights, including any party's intellectual property or assumes any liability or responsibility arising out of this report.

NOTE

Funding for this project was provided by the Federal Panel on Energy Research and Development, Department of Natural Resources Canada.

Catalogue No. M91-7/92-1990E
ISBN 0-662-17930-0

ACKNOWLEDGEMENTS

The "Passive Solar Potential in Canada: 1990-2010" project was conducted by Scanada Consultants Limited.

This study is very much the product of a team effort. Among the many contributors and reviewers, the following deserve special mention: Mark Riley of Energy, Mines and Resources, who supervised, directed and thoroughly reviewed all the stages of this project; Tim Mayo, Roger Henry, Edward Morofsky and Joel Allarie of EMR, and the Passive Solar Technical Advisory Committee (TAC), who all played a strong role in the project supervision and review process.

The work described in this report was supported by the Federal Panel on Energy Research and Development [PERD].

DISCLAIMER

This report is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of current or future status of any policy or program. Neither Canada or its ministers, officers, employees or agents makes any warranty in respect of this report or assumes any liability arising out of this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

1. INTRODUCTION

Following the 70's when fossil fuel supplies appeared limited and prices increased dramatically, Canada's building sector greatly improved and applied its knowledge to conserve energy economically by reducing heat flow through the building envelope. In the 90's and onward it is anticipated that the focus will be on environmental protection, in particular, the reduction of CO_2 emissions. Hence, environmental concerns will continue to lead to improvement of existing energy-efficient technologies and encourage exploitation of more advanced technologies. Passive solar concepts are expected to play an important role in increasing the energy efficiency of the building stock; such concepts are technically attractive and cost-effective conservation tools.

As the title suggests, the main purpose of this study is to identify and to assess the potential of passive solar technologies to improve the energy efficiency of Canada's housing and commercial building stock. While making full use of the improvements in envelope insulation and airtightness, passive solar can achieve more than can those improvements alone, through improvements in "net" solar utilization. That is, the passive solar concept uses solar gains for winter heating and daylighting, by minimizing both losses and the need for storage of excess gains; and it also minimizes both solar gains and other inward heat flows in summer, while providing effective daylighting.

1.1 Passive Solar Design

Passive solar is firstly a design concept rather than a specific product or a certain combination of components. Basically - as a primary definition - passive solar design is a matter of arranging and using the various components of a building - essentially all of them traditionally present and "paid for" - to serve other functions, to gain and utilize solar heat and light to optimal effect. It may involve building layout, exposure, and window placement. It may also involve envelope colour and texture to enhance sol-air effects. By definition, it involves a studied arrangement to maximize net solar utilization, as mentioned. That now usually involves the use of active mechanical ventilation and air-handling inside the building to move heat around and store it, at least in the normal building fabric, for release as needed. (Such a combination of passive entry and active handling was once termed "passive-hybrid", but such distinctions are blurred and serve no purpose here.)

In previous studies (Ref. 14), it has been established that such essentially "zero cost" usage of passive solar design in new house construction can achieve a solar contribution of about 25 percent of the heating load. That represents an increment of about 15% over the solar fraction of a normal, well insulated house built without attention to passive design, and the gain is achieved largely by orienting almost all windows to the south. Clearly, such effective zero-cost usage of traditional components and materials can be applied only to new house construction, and only where full exposure ("sun rights") can be enjoyed.

1.2 Passive Solar Technologies Applicable to Most Buildings

This study departs from its forerunners (Ref. 2, 13, 14) in its more singular objective to assess those solar-utilizing technologies - existing and emerging - that can add to the energy performance of buildings regardless of building shape, layout, orientation and "sun rights". High thermal performance windows are the leading example. Such technologies are complementary to any such "layout" benefits that a building may enjoy, and generally offer additional conservation potential for essentially all of the building stock. The estimates presented in this study are of the incremental benefits of these technologies in addition to those that may be in play or projected from the basic concepts of passive solar design.

1.3 Objectives

The objectives here are to:

- estimate the passive solar energy contribution in the building stock "as is", in absolute terms and as a fraction of energy requirements;
- assess the overall potential of existing and emerging technologies to increase the contribution, considering both technically possible and market-likely scenarios; and in particular
- assess, through "case studies", the specific potentials of certain technologies of clear promise, namely high thermal performance windows, daylighting and solar storage/utilization mechanisms in terms of net benefits in heating, lighting and cooling.
- In the latter regard, a further objective was added in the course of the work: to estimate the potential energy-saving contribution of various rates of uptake of high thermal performance windows in the normal window retrofit market.

The focus of this project is to identify technical feasibility of passive solar potential in existing buildings and in new construction, and also to identify opportunities and set priorities with respect to research, development and technology transfer activities.

2. SUMMARY OF METHOD

The passive solar potential is assessed using the definition of passive solar as a net solar contribution to the building energy requirements. Four building sectors are considered:

- Existing Residential (to 1988);
- New Residential (1989-2010);
- Existing Non-Residential or Commercial (to 1988); and
- New Non-Residential or Commercial (1989-2010)

Assessment of the energy conservation potential of passive solar is based, firstly, on a reconstruction of current energy consumption levels for each province and building sector using a detailed "building stock model". Stock numbers and energy consumption levels developed in this model are compared to other available statistics to verify and to improve the confidence levels of the estimates. For each building sector, building stock data, energy consumption characteristics, fuel usage, solar contribution, potential improvements in energy efficiency and overall energy performance numbers are determined from available statistics, or estimated based on certain assumptions.

Once these calculations are performed, scenarios of achievable conservation performance are developed, expressed as the following three levels of potential:

1. **ultimate potential:** a maximum probable conservation potential that would be realized if all technologies were developed to the fullest and applied universally. This "idealized" potential represents an upper limit.

2. **technically feasible potential:** a conservation potential that could be achieved if all currently available and clearly emerging technologies were applied universally.

3. **reasonably achievable market potential:** developed by postulating scenarios of market penetration of available and clearly emerging technologies which are or will be commercially attractive. The 100% market penetration rate is equivalent to the "technically feasible potential"; a fraction of that is considered reasonably achievable.

Four emerging passive solar technologies have been identified and evaluated, in such scenarios, for their incremental potential to conserve energy, first in Canada's existing residential and commercial buildings, and then in new construction to the year 2010. These technologies are: high thermal performance windows, daylighting, integrated mechanical systems, and thermal storage using phase-change material wallboard.

In this summary, the useful data on Canada's building stock are presented, and then the main findings on passive solar contributions, potentials and some details; the analytical methods and more detailed findings are reported in the main report and its appendices.

3. BUILDING STOCK TO 2010

The residential stock consists of single homes, semi-detached, row, walkups, and high-rise apartment buildings. There are 9.69 million units comprising 1,021 million m^2 floor area in the year 1988. The new residential building stock (1989-2010) is projected on the basis of net increase in the stock using historical growth rates with projected modifications. Residential stock may increase to 13.8 million units (1,494 million m^2 of floor area) by the year 2010.

The commercial building stock consists of office buildings, retail stores and malls, schools and universities, warehouses, factories and plants, hotels, theatres and recreational facilities, hospitals, institutional buildings, religious places, garages and other miscellaneous buildings. The existing building stock consists of 0.59 million units comprising 573 million m^2 floor area. Future building stock is projected on the basis of net increase in the buildings using the historical growth rates, with projected modifications, for each type of building. Commercial building stock may increase to 0.89 million units (858 million m^2 floor area) by the year 2010.

4. SUMMARY OF PASSIVE SOLAR POTENTIALS

4.1 Existing Residential Stock: Retrofit Potential

The single technology that clearly can be applied to existing dwellings to improve energy performance is high thermal performance window technology. A technically feasible potential of 136 PJ/yr is possible in the year 2010 by replacing existing windows with high thermal performance windows (RSI 1). A case study on these windows showed that, with an annual uptake rate of 4.5% in window replacement in existing buildings to the year 2000 and 3.5% increase thereafter, the passive solar contribution would be 36 PJ/yr in the year 2010. The above rates of uptake in existing residential buildings, which are rather normal replacement rates, would replace windows in 3.1 million units, representing 32% of existing residential building stock by the year 2010.

4.2 New Residential Construction (from 1989-2010)

The promising passive solar technologies identified with new residential construction are: (1) high thermal performance windows, (2) thermal storage, and (3) integrated mechanical systems. Virtually all new houses and apartment buildings can currently be built with these new technologies to make them more efficient users of solar energy. A "technically feasible" potential of 53 PJ/yr is possible in the year 2010 by using the above currently available technologies.

The "reasonably achievable" market penetration scenario is:

- With a projected 7% market for high performance windows in 1990, increasing to 34% in the year 2000, and a 67% market in the year 2010, windows in new residential buildings will contribute 14 PJ/yr in 2010. It is projected that 1.3 million new residential buildings will then use these windows, comprising 32% of that stock.

- The use of integrated mechanical system in new residential buildings, at a rate of 3.5% in 1990, increasing to 16% in the year 2000, and 66% in the year 2010, will contribute 10 PJ/yr in the year 2010. About 23% of new residential buildings will use these integrated mechanical system by that time.

- The use of thermal storage options such as phase-change material wallboards in new residential buildings will contribute 1 PJ/yr in the year 2010. The PCM wallboard technology is still under development and is expected to be commercially available by the year 1994. It is projected that about four percent of new residential building stock will use this technology by the year 2010.

In sum, new residential construction holds a "reasonably achievable" promise of a passive solar contribution of 25 PJ/yr in the year 2010. That can be gained by using the emerging passive solar technologies in less than 30% of new residential construction.

4.3 Retrofit Potential in Existing Commercial Buildings

The main passive solar technologies that can be retrofitted to existing commercial buildings are high thermal performance windows and daylighting. A technically feasible potential using today's best available window technology and daylighting is about 100 PJ/yr in the year 2010. In a reasonably achievable market penetration, where replacement of windows will occur in less than 20% of existing commercial buildings and retrofit for daylighting will be done in 2.5% of buildings, the energy contribution will be 23 and 3 PJ/year respectively, for a total of 26 PJ per year in 2010.

4.4 New Commercial Buildings (from 1989-2010)

The promising passive solar technologies identified with new commercial construction are: (1) high thermal performance windows, (2) daylighting, and (3) thermal storage. Virtually all new commercial buildings could currently be built with these new technologies to make them more efficient users of solar energy. Integrated mechanical systems are already featured in much of new commercial construction to good effect. A "technically feasible" potential of 74 PJ/yr is possible in the year 2010 by using the above currently available technologies.

The "reasonably achievable" market penetration scenario for the new commercial buildings is as follows:

- It is projected that high performance windows (RSI 1) will be used in 22% of new commercial buildings, contributing 11 PJ/yr in the year 2010.

- The major contribution to passive solar will be gained from the use of daylighting. About 35% of the new commercial construction will utilize daylighting. The passive solar contribution will be 31 PJ/yr in the year 2010, in this scenario.

- Thermal storage technologies for commercial buildings are well developed and in use. The use of innovative thermal storage options, such as PCM wallboard, will contribute 2 PJ/yr in the year 2010 in this scenario.

In sum, new commercial construction holds reasonably achievable promise of a passive solar contribution of 44 PJ/yr in the year 2010. That can be gained by using the emerging windows, daylighting, and thermal storage technologies in about 35% of new commercial construction.

4.5 Summary of Passive Solar Potential

As shown in Table 1 there exists a technically feasible <u>incremental</u> potential of 363 PJ/year with currently available technologies. A reasonably achievable market potential is 131 PJ/year in the year 2010.

Table 2 shows the estimates of reasonably achievable solar utilization/energy conservation potential in four building sectors which may be achieved by the use of clearly emerging passive solar technologies. Figure 1 shows the incremental passive solar potential by the year 2010.

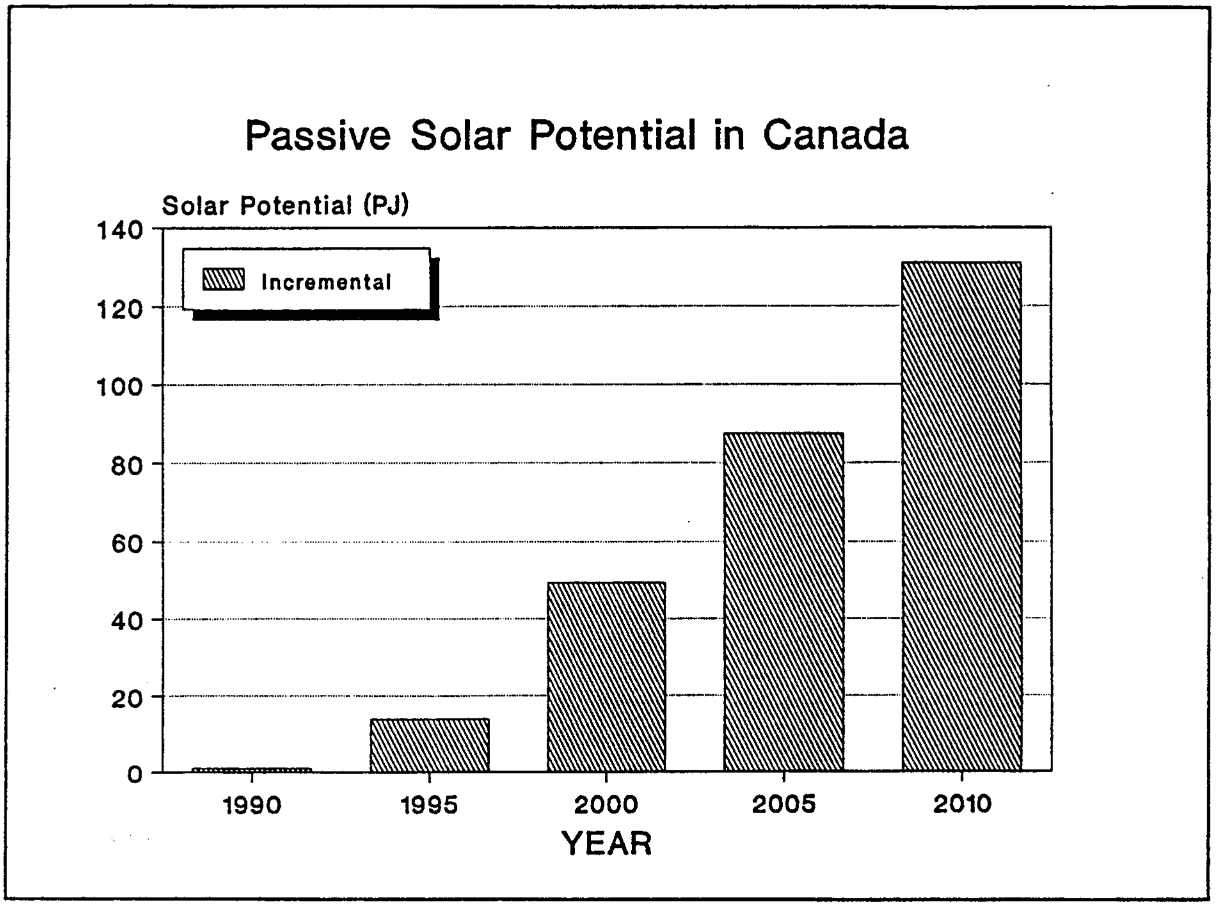
Table 1: Summary of Passive Solar Potential in Buildings in the Year 2010.

	Ultimate Passive Solar Potential (PJ/Year)	Technically Feasible Potential (PJ/Year)	Reasonably Achievable Market Potential (PJ/Year)
1. Existing Residential Retrofit Potential (to 1988)	296	136	36
2. New Residential (1989-2010)	151	53	25
3. Existing Commercial Retrofit Potential (to 1988)	172	100	26
4. New Commercial (1989-2010)	108	74	44
TOTAL	727	363	131

Table 2: Estimates of Reasonably Achievable Passive Solar Potential in the Year 2010.

Emerging Technology	Residential (PJ/yr)		Commercial (PJ/yr)		Total (PJ/yr)
	Existing	New	Existing	New	
High Performance Windows	36	14	23	11	84
Daylighting	-	-	3	31	34
Integrated Mechanical Systems	-	10	-	-	10
Thermal Storage	-	1	-	2	3
Total	36	25	26	44	131

Figure 1: Passive Solar Potential In the Year 2010.



5. CONCLUSIONS

Using current and clearly emerging passive solar technologies, the technically feasible potential for solar utilization / energy conservation has been identified as 363 PJ/year by the year 2010. The incentive to promote the acceptance of these technologies is indeed very high. A reasonably achievable market potential is 131 PJ/year in the year 2010.

Exploitation of such a large passive solar potential would require emphasis on research and development activities directed towards products with very good potential for commercialization and marketing. The clearly emerging passive solar technologies, such as high thermal performance windows, daylighting and integrated mechanical systems, should be prioritized for further research, development and demonstration. Clearly, the new high performance windows alone constitute a "breakthrough" that offers more potential for solar utilization and energy conservation than any other single change in buildings. The industry, as well as federal and provincial energy ministries, should support such R&D as a highest energy conservation priority. Energy supply and economics, and the matter of the environment, are the incentives for such R&D.

RÉSUMÉ

1. INTRODUCTION

La crise du pétrole des années 1970 a servi à sensibiliser l'industrie du bâtiment aux limites des ressources en combustibles fossiles et aux conséquences d'une escalade des prix et a amené ce secteur de l'industrie à améliorer sa performance et à se pencher sur les économies d'énergie réalisables par la diminution des échanges de chaleur attribuables à l'enveloppe du bâtiment. A compter des années 1990, il est prévu que l'emphase portera surtout sur la protection de l'environnement et plus particulièrement sur la réduction des émissions de CO^2. Ainsi, les préoccupations environnementales continueront de motiver l'amélioration des technologies existantes axées sur l'efficacité énergétique et d'encourager l'exploitation des technologies de pointe. Le concept technologique du solaire passif est appelé à jouer un rôle de premier ordre en ce qui concerne l'efficacité du parc bâtiment; ce concept technologique présentant à la fois attrait sur le plan technique et rentabilité sur le plan énergétique.

Comme le laisse présager son titre, la présente étude vise principalement à définer et à évaluer les possibilités offertes par les techniques des systèmes solaires passifs des bâtiments résidentiels et commerciaux du Canada. Le recours à toutes les améliorations que l'on peut apporter à l'étanchéité et à l'isolation de l'enveloppe permet, certes, une certaine économie d'énergie mais ne peut se comparer à l'efficacité énergétique du système solaire passif d'un bâtiment conçu à cette fin. Le concept du système solaire passif tire pleinement profit des apports solaires pour l'éclairage de jour et le chauffage durant l'hiver, tout en réduisant les déperditions rattachées à ces deux opérations et en supprimant la nécessité "d'évacuer" les calories excédentaires. Enfin, ce type de systèmes minimise les apports solaires et autres gains calorifiques durant l'été tout en assurant un éclairage de jour adéquat.

1.1 Conception des systèmes solaires passifs

Le solaire passif est essentiellement un mode de conception des bâtiments et non un produit particulier ou une combinaison donnée de composants. Fondamentalement, la conception de systèmes solaires passifs peut être définie comme le choix et l'articulation des divers éléments d'un bâtiment - éléments que l'on retrouve généralement dans un bâtiment traditionnel et dont le coût aura déjà été "assimilé" à d'autres fonctions de l'ouvrage - visant à recueillir l'énergie solaire et à l'utiliser de façon optimale à des fins de chauffage et d'éclairage. Les concepts qui entrent en jeu peuvent englober une architecture, une orientation et une fenestration résolument axées vers une "forte exposition" au soleil. Les couleurs et le type de matériaux composant l'enveloppe pourront également augmenter les apports sol-air. Les systèmes solaires passifs, nous le rappelons, sous-tendent par définition un agencement soigneusement étudié en vue de tirer pleinement profit de tous les apports d'ensoleillement. Ce type de conception englobe habituellement l'intégration d'appareils de ventilation et de conditionnement de l'air actifs assurant le transfert et le stockage de la chaleur dans le bâtiment, tout au moins dans les composants courants de l'enveloppe, en vue d'une restitution au moment requis. (Une telle combinaison d'apports solaires passifs et d'appareils de traitement actifs a déjà été nommé "système solaire passif hybride", mais ces distinctions sont bien ténues et ne nous semblant pas utiles.)

Dans les études antérieures (réf. 14), il a été établi que de telles applications "sans frais" de la conception de systèmes solaires passifs dans la construction neuve peuvent fournir un apport calorifique correspondant à environ 25 pour cent des charges de chauffage, ce qui représente une hausse de près de 15 pour cent de l'apport solaire courant d'une maison ordinaire adéquatement isolée mais construite sans tirer avantage des systèmes solaires passifs. Cette augmentation est en grande partie obtenue par une orientation sud de la quasi-totalité des fenêtres. Il semble donc très claire que des applications "sans frais" aussi efficaces des éléments et matériaux traditionnels peuvent être mises à profit uniquement dans des constructions neuves jouissant d'une pleine exposition au soleil ("droits à l'ensoleillement").

1.2 Champ d'application des techniques solaires passives

La présente étude se distingue des précédentes (réf. 2, 13 et 14) par un objectif très particulier consistant à évaluer les techniques faisant appel à l'énergie solaire - techniques reconnues aussi bien que nouvelles - pouvant accroître la performance énergétique des bâtiments sans égard à l'architecture, l'articulation, l'orientation et les "droits à l'ensoleillement" de ces bâtiments. Les fenêtres à haute performance énergétique en sont un excellent exemple. Les techniques susmentionnées s'ajoutent à toute configuration avantageuse pouvant augmenter la performance d'un bâtiment et offrent généralement des possibilités additionnelles de conservation de l'énergie pour la grande majorité du parc immobilier. Les estimations présentées dans cette étude portent sur les apports calorifiques additionnels attribuables à ces techniques et viennent se combiner aux avantages que l'on peut tirer ou que l'on prévoit tirer des concepts fondamentaux inhérents aux systèmes solaires passifs.

1.3 Objectifs

Les objectifs visés se lisent comme il suit :

- estimer les apports solaires passifs "actuels" du parc immobilier, exprimés d'une part ~~en~~ termes absolus et d'autre part telle une fraction des besoins énergétiques;

- évaluer les possibilités globales offertes par les techniques reconnues et nouvelles en ce qui concerne les apports solaires, compte tenu à la fois de la faisabilité technique des solutions considérées et de leur intérêt comercial; et de façon plus particulière;

- déf~~i~~ner, par des études "de facilité—d'exécution", les possibilités précises offertes par diverses techniques très prometteuses, notamment l'installation de fenêtres à haute performance énergétique, l'exploitation de la lumière du jour, les systèmes mécaniques de stockage et de restitution de l'énergie solaire, en termes d'apports calorifiques nets servant au chauffage, à l'éclairage et au refroidissement;

- sous ce dernier aspect, un autre objectif s'est ajouté au cours du projet, soit celui consistant à estimer les éventuelles économies d'énergie obtenues aux différents taux d'utilisation des fenêtres à haute performance énergétique disponibles pour le marché courant de réfection des fenêtres.

Ce projet vise à identifier la faisabilité technique des technologies en solaire passif pour les bâtiments existants de même que pour les constructions neuves. Également, le projet sert à présenter les opportunités ainsi que suggerer les priorités quant aux activités de recherche, développement et transfert de la technologie.

2. SOMMAIRE DE LA MÉTHODE UTILISÉE

Les possibilités offertes par les systèmes solaires passifs sont évaluées en fonction de la définition d'apports solaires passifs par laquelle on entend la proportion nette des besoins énergétiques du bâtiment satisfaits à l'aide de l'énergie solaire. Quatre secteurs de l'industrie du bâtiment sont étudiés :

- les bâtiments résidentiels existants (construits avant 1989);

- les bâtiments résidentiels neufs (construits entre 1989 et 2010);

- les bâtiments commerciaux ou autres que résidentiels existants (construits avant 1989); et

- les bâtiments commerciaux ou autres que résidentiels neufs (construits entre 1989 et 2010).

L'estimation des économies d'énergie pouvant être réalisées à l'aide de systèmes solaires passifs repose tout d'abord sur une révision des niveaux actuels de consommation énergétique de chaque province et de chaque secteur de l'indstrie du bâtiment au moyen d'un "parc immobilier type" très détaillé. Les niveaux de consommation énergétique et le nombre de bâtiments composant ce parc type sont comparés aux autres données statistiques disponibles afin de vérifier et d'accroître la fiabilité des estimations présentées. Pour chaque secteur de l'industrie, les données relatives du parc immobilier, aux niveaux de consommation énergétiques, à la consommation de combustibles, aux apports solaires, aux éventuelles améliorations de l'efficacité énergétique et aux performances énergétiques globales sont établies à l'aide des statistiques disponibles ou encore d'estimations fondées sur certains postulats.

Après l'exécution de ces claculs, différentes situations ont été imaginées afin de représenter des taux de conservation de l'énergie distincts correspondant aux trois niveaux d'apports solaires suivants :

1. **performance maximale** : taux de conservation de l'énergie maximal probable que l'on obtiendrait en tirant pleinement avantage d'une application globale de toutes les techniques. Ce taux de conservation "idéal" représente le taux maximal possible.

2. **performance techniquement réalisable** : taux de conservation de l'énergie que l'on pourrait obtenir en tirant avantage d'une application globale de toutes les techniques actuellement disponibles ou nouvellement reconnues.

3. **performance porbable du marché** : taux de conservation l'énergie obtenu en concevant divers taux de pénétration du marché par les techniques disponibles ou nouvellement reconnues qui sont ou qui seront commercialement attrayantes. Une pénétration complète du marché (100 %) correspond à la performance techniquement réalisable tandis que la performance probable du marché équivaut à une fraction de la performance techniquement réalisable.

Quatre éléments reconnus des systèmes solaires passifs ont été définis et les apports calorifiques additionnels qu'ils permettent d'exploiter, dans les situations susmentionnées, ont été évalués, d'une part pour les bâtiments résidentiels et commerciaux existants du Canada et, d'autre part, pour les bâtiments neufs construits d'ici l'an 2010. Ces techniques comprennent les fenêtres à haute performance énergétique, l'exploitation de la lumière du jour, les réseaux mécaniques intégrés et le stockage de l'énergie thermique à l'aide de panneaux muraux à changement de phase (MCP).

Le présent résumé réunit les données appropriées relatives au parc immobilier canadien, les principales conclusions concernant les apports solaires passifs, les taux de conservation et enfin un certain nombre de détails pertinents. Les méthodes analytiques et les conclusions détaillées sont présentées dans le rapport général et les annexes qui l'accompagnent.

3. LE PARC IMMOBILIER D'ICI L'AN 2010

Le parc immobilier résidentiel comprend les maisons unifamiliales, les maisons jumelées, les maisons en rangée, les logements à l'étage de bâtiments sans ascenseur et les bâtiments d'habitation de grande hauteur. Le parc immobilier se composait, en 1988, de 9,69 millions de logements occupant 1021 millions de mètres carrés de surface de plancher. L'importance du nouveau parc immobilier résidentiel (logements construits entre 1989 et 2010) a été extrapolée d'après l'augmentation nette de nombre de logements, en fonction des taux de croissance antérieurs et des modifications projetées. Le parc immobilier résidentiel pourrait atteindre 13,8 millions de logements, soit 1494 millions de mètres carrés de surface de plancher, d'ici l'an 2010.

Le parc immobilier commerical comprend les immeubles de bureaux, les commerces de détail et les centres commerciaux, les éstablissements scolaires, les universités, les entrepôts, les usines et établissements industriels, les hôtels, les théatres et centres récréatifs, les hôpitaux, les éstablissements publics ou réservés au culte, les garages et autres bâtiments divers. Le parc immobilier actuel se compose de 0,59 million d'unités occupant 573 millions de mètres carrés de surface de plancher. L'importance du futur parc immobilier a été extrapolée d'après l'augmentation nette du nombre de bâtiments, en fonction des taux de croissance antérieurs et des modifications projetées pour chaque type de bâtiments. Le nombre de bâtiments du parc immobilier commercial pourrait atteindre 0,89 million d'unités, soit 858 millions de mètres carrés de surface de plancher, d'ici l'an 2010.

4. SOMMAIRE DES APPORTS SOLAIRES PASSIFS

4.1 Possibilités de réfection du parc immobilier résidentiel existant

L'unique technique pouvant s'appliquer sans l'ombre d'une doute aux logements existants en vue d'accroître leur performance énergétique est celle des fenêtres à haute performance énergétique. Une performance techniquement réalisable de 136 PJ/année pourra être obtenue en l'an 2010 si l'on remplace les fenêtres existantes par des fenêtres à haute performance énergétique (RSI 1). Une étude de cas portant sur cette catégorie de fenêtres a montré que, avec le remplacement chaque année de 4,5 pour 100 des fenêtres des bâtiments existants d'ici l'an 2000 et une augmentation de 3,5 pour 100 de l'usage de ce type de fenêtres par la suite, les apports solaires passifs s'élèveraient à <u>36 PJ/année</u> en l'an 2010. Les pourcentages susmentionnés pour le parc immobilier résidentiel existant, <u>lesquels correspondent aux taux de remplacement courants</u>, représentent le remplacement des fenêtres de 3,1 millions de logements, soit 32 pour 100 du parc immobilier résidentiel de l'an 2010.

4.2 Bâtiments résidentiels neufs (construits entre 1989 et 2010)

Les techniques solaires passives prometteuses associées aux constructions résidentielles neuves englobent : 1) les fenêtres à haute performance énergétique, 2) le stockage de l'énergie thermique et 3) les réseaux mécaniques intégrés. Ces techniques peuvent être intégrées à la quasi-totalité des maisons et immeubles d'habitation neufs afin d'utiliser plus efficacement l'énergie solaire. L'utilisation des techniques courantes mentionnées plus haut permettra d'obtenir, en l'an 2010, une performance techniquement réalisable de 53 PJ/année.

La situation étudiée en ce qui a trait à la pénétration du marché "probable" est la suivante :

- en supposant, par projection, que 7 pour cent des logements constituant le marché en 1990 soient dotés de fenêtres à haute performance énergétique, proportion s'élevant à 34 pour 100 en l'an 2000 et à 67 pour 100 en l'an 2010, les seules fenêtres des constructions résidentielles neuves représenteront 14 PJ/année en 2010. Selon cette projection, 32 pour 100 de ce parc immobilier, soit 1,3 million de maisons neuves, seraient alors équipées de ces fenêtres;

- l'utilisation de systèmes mécaniques intégrés dans les constructions résidentielles neuves, dans une proportion de 3,5 pour 100 en 1990, proportion atteignant 16 pour 100 en l'an 2000 et 66 pour 100 en l'an 2010, représente 10 PJ/année en 2010. Près de 23 pour 100 des constructions résidentielles neuves seront alors équipées de ces systèmes mécaniques intégrés;

- l'utilisation de dispositifs de stockage thermique tels que les panneaux muraux à changement de phase (MCP) représentera

1 PJ/année en 2010 dans les bâtiments résidentiels neufs. La technique des panneaux MCP n'est pas encore au point; toutefois, la commercialisation de ce type de panneaux est prévu pour 1994. On estime qu'environ 4 pour cent des bâtiments résidentiels neufs tireront avantage de cette nouvelle technique en l'an 2010.

Somme toute, les constructions résidentielles neuves pourraient offrir une "performance probable du marché" de 25 PJ/année en matière d'apports solaires passifs en l'an 2010, performance qui pourra être obtenue en ayant recours aux techniques nouvellement reconnues de systèmes solaires passifs dans moins de 30 pour cent des constructions neuves du secteur résidentiel.

4.3 Possibilités de réfection des bâtiments commerciaux existants

Les principales techniques de systèmes solaires passifs pouvant être adaptées aux bâtiments commerciaux existants comprennent l'exploitation de la lumière du jour et la pose de fenêtres à haute performance énergétique. Une performance techniquement réalisable obtenue à l'aide des meilleures fenêtres actuellement sur le marché et d'une utilisation optimale de la lumière du jour correspondrait à environ 100 PJ/année en 2010. Dans le cas d'une performance probable du marché où moins de 20 pour cent des fenêtres des bâtiments commerciaux existants seraient remplacés et où 2,5 pour cent de ces bâtiments seraient réaménagés en vue de tirer profit de la lumière du jour, l'apport énergétique serait de 23 pour cent et de 3 PJ/année respectivement, soit l'équivalent de 26 PJ par année en 2010.

4.4 Bâtiments commerciaux neufs (construits entre 1989 et 2010)

Les techniques solaires passives prometteuses associées aux constructions commericales neuves englobent : 1) les fenêtres à haute performance énergétique, 2) l'exploitation de la lumière du jour et 3) le stockage de l'énergie thermique. Ces techniques peuvent être intégrées à la quasi-totalité des bâtiments commerciaux neufs afin d'utiliser plus efficacement l'énergie solaire. Les systèmes mécaniques intégrés ont déjà été avantageusement mis à contribution dans une grande partie de ce secteur de l'industrie. L'utilisation des techniques courantes mentionnées plus haut permettra d'obtenir, en l'an 2010, une performance techniquement réalisable de 74 PJ/année.

La situation étudiée en ce qui a trait à une pénétration "probable" de ce marché est la suivante :

- selon nos projections, 22 pour cent des bâtiments commerciaux neufs seraient dotés de fenêtres à haute performance énergétique (RSI 1), fournissant ainsi un apport de 11 PJ/année en 2010;

- les principaux apports solaires passifs proviendront de l'utilisation optimale de la lumière du jour. Environ 35 pour cent des constructions commerciales neuves seraient dotés des équipements permettant ce type d'exploitation, situation permettant de tirer des apports calorifiques de 31 PJ/année en 2010;

- les techniques de stockage de l'énergie thermique adaptées aux bâtiments commerciaux sont bien connues et déjà répandues. Dans la situation précédemment décrite, l'emploi de nouvelles techniques de stockage thermique telles que les panneaux MCP fournira des apports solaires de 2 PJ/année en 2010.

Somme toute, les bâtiments commerciaux neufs pourraient offrir une performance probable du marché de 44 PJ/année en matière d'apports solaires passifs en l'an 2010, performance qui pourra être obtenue en ayant recours aux techniques nouvellement reconnues incluant les fenêtres à haute performance énergétique, l'exploitation de la lumière du jour et le stockage de l'énergie thermique dans près de 35 pour cent des bâtiments commerciaux neufs.

4.5 Résumé des apports solaires passifs

Comme le montre le tableau 1, les techniques actuellement disponibles offrent une performance techniquement réalisable de 363 PJ/année et une performance probable du marché de 131 PJ/année en l'an 2010.

Le tableau 2 indique que les estimations des taux de conservation ou d'exploitation de l'énergie solaire techniquement réalisables des 4 secteurs de l'industrie du bâtiment, taux qui pourront être concétisés par la mise à contribution des techniques solaires passives nouvellement reconnues. L'illustration 1 présente les apports solaires passifs incrémentaux jusqu'à l'année 2010.

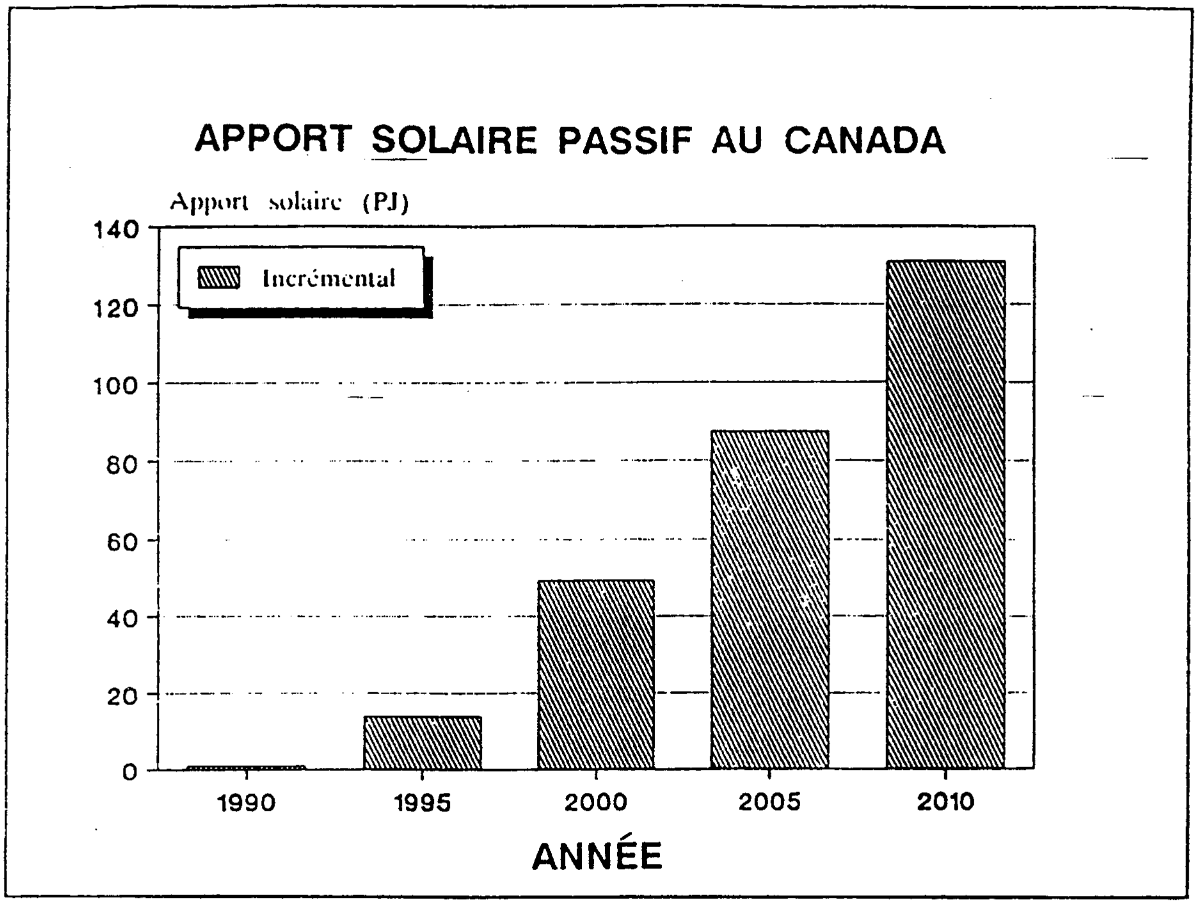
Tableau 1 : **Résumé des apports solaires passifs dans les bâtiments en 2010**

	Performance maximale (PJ/année)	Performance techniquement réalisable (PJ/année)	Performance probable du marché (PJ/année)
Réfection des bâtiments résidentiels existants (avant 1989)	296	136	36
Bâtiments résidentiels neufs (entre 1989 et 2010)	151	53	25
Réfection des bâtiments commerciaux existants (avant 1989)	172	100	26
Bâtiments commerciaux neufs (entre 1989 et 2010)	108	74	44
TOTAL	727	363	131

Tableau 2 : **Estimations de la performance probable du marché des systèmes solaires passifs en 2010**

Techniques nouvellement reconnues	Bâtiments residentiels (PJ/année)		Bâtiments commerciaux (PJ/année		Total (PJ/ année)
	existants	neufs	existants	neufs	
Fenêtres à haute performance énergétique	36	14	23	11	84
Exploitation de la lumière du jour	--	--	3	31	34
Systèmes mécaniques intégrés	--	10	--	--	10
Stockage de l'énergie thermique	--	1	--	2	3
TOTAL (PJ/année)	36	25	26	44	131

Illustration 1 : Apport Solaire Passif en L'an 2010



5. CONCLUSIONS

L'intérêt de promouvoir l'intégration des techniques courantes et nouvellement reconnues de systèmes solaires passifs est nécessairement très grand puisque que l'utilisation de ces techniques offre une performance techniquement réalisable en matière de conservation ou d'exploitation de l'énergie solaire de 363 PJ/année en l'an 2010, la performance probable du marché étant estimée à 131 PJ/année.

L'exploitation d'apports solaires passifs aussi considérables exigerait que l'on favorise tout particulièrement les activités de recherche et de développement axées vers les produits ayant un potentiel intéressant pour la commercialisation et la mise en marché. Les techniques solaires passives nouvellement reconnues telles que les fenêtres à haute performance énergétique, l'utilisation optimale de la lumière du jour et les systèmes mécaniques intégrés devraient figurer au premier plan des projets de recherche et de développement, et des démonstrations à venir.

Il ressort clairement que les fenêtres à haute performance énergétique permettraient, à elles seules, une percée offrant des apports plus considérables en ce qui concerne la conservation et l'exploitation de l'énergie solaire que toute autre modification pouvant être apportée aux bâtiments. L'industrie, de même que les ministères fédéral et provinciaux de l'Énergie, devrait faire de la recherche et du développement sa priorité dans le domaine de la conservation énergétique. Les ressources énergétiques, les conditions économiques et la question environnementale sont les principaux enjeux de ces projets de recherche et de développement.

1. INTRODUCTION

In the last two decades, Canada's building industry has improved its knowledge on how to conserve energy economically by reducing heat flow through the building envelope. The solar energy contribution by natural means, "passive solar", has helped in further reducing auxiliary heating and cooling energy requirements. Passive solar technology integrates the collection, distribution and storage of energy into the design of the building itself, and is therefore integral to good building design. Integration of passive solar features in buildings results in two major benefits: (1) the savings of non-renewable resources, and (2) the savings in pollution costs resulting from conventional space heating, cooling and lighting methods.

The solar energy transmitted through windows accounts for 8 to 20% of space heating energy requirements. Until recently, the building community has had little means or incentive to increase the passive solar contribution much above this level. Improvements in window technology, advancements in building mechanical systems, and refinements in passive solar design methods, now make it possible to increase the substantial amount of passive solar energy an energy-efficient building can use while maintaining occupant comfort.

Passive solar design concepts are, typically, inter-woven in low-energy building concepts; hence it is difficult to separate or define them from other low-energy conservation measures. Passive solar design concepts associated with building components are:

- **layout:** orientation of building elements and landscaping with regard to "solar facing."
- **collection:** solar energy entry through windows; daylighting; and sol-air effect on reducing heat losses.
- **utilization:** efficient utilization of net gains in meeting, lighting, space heating and cooling requirements: thermal storage options with phase-change material (e.g., drywall), efficient energy transfers within the building (e.g., integrated mechanical systems).

The main purpose of this project is to provide data on the energy conservation potential which can be achieved through the use of passive solar design features and components in the residential and commercial buildings. The main objective is to identify technical feasibility of passive solar potential in existing buildings and in new construction, and also to identify opportunities and set priorities with respect to research, development and technology transfer activities.

This study focuses on passive solar technologies which are intended to enhance the energy performance of buildings regardless of building shape, layout, orientation, lot size, and so on. This report assesses to what extent builders, designers, and building owners can improve the energy performance of their buildings by judicious material and component selection.

1.1 Objectives

The objectives here are to:

- estimate the passive solar energy contribution in the building stock "as is", in absolute terms and as a fraction of energy requirements;

- assess the overall potential of existing and emerging technologies to increase the contribution, considering both technically possible and market-likely scenarios;

- assess, through case studies, the specific potentials of certain technologies of clear promise, namely high thermal performance windows, daylighting and solar storage/utilization mechanisms in terms of net benefits in heating, lighting and cooling; and

- recommend research directions and means of harnessing passive solar potential.

A further objective was added in the course of the work: to estimate the potential energy-saving contribution of various rates of uptake of high thermal performance windows in the normal window retrofit market in existing housing.

1.2 Definition of Passive Solar

Passive solar is firstly a design concept rather than a specific product or a certain combination of building components. Basically, as a primary definition, passive solar contribution is a matter of arranging and using the various components of a building to gain and utilize net solar heat and light to optimal effect. The energy balance of solar gains and heat losses through the building component provides the "net" conservation effect. This net effect is a contribution to the building's energy needs.

The above definition of passive solar contribution can be applied to various building components and design concepts in a consistent manner. The scope of this definition is limited to those building components or concepts which are part of solar exposure, collection, and efficient utilization of solar energy. It may involve the following:

- the use of windows to maximize the "net" conservation effect to reduce auxiliary heating or cooling requirements;

- the use of daylighting to reduce electric lighting and cooling requirements;

- the use of active mechanical ventilation and air-handling inside the building to move solar heat around and store it, at least in the normal building fabric, for release as needed;

- a studied arrangement to maximize net solar utilization, such as in the use of transparent insulation, or in the use of solar dynamic walls;

- building layout, exposure, and window placement with a solar facing bias;

- envelope colour and texture to enhance sol-air effects (the reduction of outward heat flow by virtue of sun-warmed outer portions of the envelope).

The passive solar potential, as estimated in this study, is an incremental potential. The passive solar energy contribution in existing residential and commercial buildings in the year 1989 is considered as a reference.

According to the above definition, a concept of "Energy Performance Index of the Solar Aperture" is introduced here for windows. This index is an algebraic summation of all energy flows through the solar aperture over the year divided by the gross area of the aperture.

$$\mathbf{EPI_{Building\ Component} = [SOLAR_{Gain} - HEAT\ LOSSES] \ / \ Area\ of\ Solar\ Aperture}$$

For example, the effect of different types of windows in terms of passive solar contribution can be estimated as a net reduction in space heating or cooling requirements. This definition gives the net effect of solar energy gains as a whole and the improvements to its thermal resistance. If we had followed the definition based only on solar gains through the windows, then the high performance windows would have been considered as having less solar energy potential (a high thermal performance window has higher thermal resistance and relatively lower solar transmittance). But the passive solar definition based on net gains -an energy balance of solar energy transmitted through the window as against heat losses - the higher thermal resistance component of windows can reflect to the "energy credit" of the passive solar. The net effect can be estimated using the whole building energy balance, analyzing the impact of different types of windows. This definition streamlines the effect of passive solar energy contribution in both space heating and cooling requirements.

Daylighting is also considered as a passive solar contribution. The net reduction in electric lighting energy requirements due to daylighting is considered as a passive solar contribution. Increased utilization of the solar energy component by means of thermal storage and mechanical systems is also considered as a passive solar contribution.

Thus, the passive solar contribution is the "net" (energy balance of solar gains and heat losses) energy conservation effect to reduce conventional heating or cooling requirements in buildings. The passive solar contribution in the year 2010 is estimated as an incremental potential to current passive solar energy contribution, as in the year 1989.

1.3 Report Organization

This report is organized in the following components:

- Section 2 is a brief review of the background and progress in Canadian research and development efforts in passive solar.
- Section 3 presents assessments of passive solar potential in: existing residential (up to 1988); new residential (1989-2010); existing commercial (up to 1988); and new commercial (1989-2010).
- Section 4 presents a technical and economic assessment of passive solar technologies in the form of various case studies. These include high thermal performance windows, daylighting, integrated mechanical systems and thermal storage wallboards.
- Section 5 presents various market scenarios to show the impact of varying degrees of acceptance and integration of passive solar design concepts and components.
- Section 6 summarises the impediments to market penetration of passive solar technologies.
- Section 7 lists the conclusions.

2. BACKGROUND

Energy conservation and passive solar utilization have played hand-in-hand in reducing space heating and cooling loads for Canadian buildings.

In this section, a brief literature review is presented (i) to show the current status of passive solar technology in Canada, (ii) to review the Canadian passive solar achievements, and (iii) to describe the previous passive solar potential studies.

2.1 Historical Context

At the start of the 1970s, only a small number of researchers and entrepreneurs were seeking to produce economical energy from renewable technologies. The 1973 Arab Oil Embargo, however, caused a sudden increase in the price of conventional energy production and consumption. For the western world, the prospects of very high-priced energy were real and seen to be crippling for economies that were based on low energy costs. In energy "guzzling" nations such as Canada - the world's heaviest consumer of energy per capita - the prospects were grim. With the price of oil escalating rapidly, and with increasing public awareness that cheaper substitutes could be utilized, major efforts were launched in North America and Scandinavia to develop the technologies necessary to reduce dependence on conventional energy sources.

In early 1974, the Canadian government reacted to the need for alternative energy resources. As a result a comprehensive Task Force on Energy Research and Development was formed. The Task Force proceeded to set up the Office of Energy Research and Development (OERD). In addition, the inter-departmental Panel on Energy Research and Development (PERD) was formed in 1975 to review and assess federal energy R&D and to develop tasks and research programs to be managed by selected federal departments and agencies with expertise in various technical areas[1].

The National Research Council was selected as the federal agency with the responsibility of managing the renewable energy tasks and programs. The major research and development work was contracted out to the private sector. Research and performance testing of systems was primarily done at several universities, and product development and commercialization was done by manufacturers and engineering consultants.

By 1984/85, NRC was spending about $2 million in the field of passive solar energy[2]. With the elimination of the NRC's Energy Division in 1985, the renewable program is being managed by Energy, Mines and Resources (EMR). From 1985 to 1989 EMR has spent nearly $5.2 million in supporting the development of passive solar energy in this country.

2.2 Passive Solar Research and Development Program

The National Research Council began its research efforts on passive solar technologies in 1978. Initial research focused on calculating and quantifying solar gains and on qualitative performance analysis. NRC built a Passive Solar Test Facility, comprising of three test huts, for developing performance monitoring procedures and also to try new emerging passive solar concepts[3, 4]. NRC's Passive Solar Test Facility was used for intensive "Level A" performance monitoring, which gathered minute-by-minute data for five years[5]. [Level A monitoring involves a high degree of experimental control, leading to reproducible measurements and well-documented results. Level A data is intended to validate the design algorithms and to provide the basic data for evaluating the accuracy of design predictions.] This monitoring and further analysis of data provided an immense insight into the interaction of solar gains and building components. In addition, this sophisticated facility provided data for the International Energy Agency to validate its member countries' computer design tools. The monitoring analyses also helped in the development of various passive solar design procedures and computer programs, such as HOT-2000 and ENERPASS[6].

One of the earliest Canadian demonstrations of passive solar technologies was the Saskatchewan Conservation House in 1978 - a publicly funded project[7, 8]. This house demonstrated the following passive solar technologies:

- a well-sealed and caulked vapour barrier,
- high insulation levels in the ceiling, walls and floor,
- major windows on south orientation - the passive solar gains through these windows accounted for 44 per cent of the heat requirement,
- a waste water heat exchanger,
- a domestic solar hot water system,
- night-time shutters on windows during the heating season, and
- overhangs for summer shading to avoid overheating.

The monitored data and thermal performance data obtained from this demonstration house showed that passive solar heating can contribute a large fraction - up to 50 per cent - of space and water heating requirements. These results generated enthusiasm and paved the way for innovative passive solar designs across the nation.

In 1980, a project was undertaken to study ten practical passive solar houses in Eastern Canada under contract for the National Research Council[9]. This study included the energy conservation economics, construction methods, practicality, and home-owners' perceptions of their passive solar homes. The major conclusion of this study was that with little or no extra first cost, passive solar house design can yield appreciable savings in energy - in the range of 25 to 35 per cent.

From 1983 to 1986, over 20 solar houses across Canada were subjected to simpler "Level B" monitoring procedures. Design features of those houses included sunspaces, super-insulation and remote thermal storage, a Trombe wall, unheated buffer spaces, and thermal storage in a variety of building materials. The results showed an average solar contribution of 28 per cent - a significant increase over the 8 per cent contribution typical for conventional housing[10]. [Level B uses the monthly energy balance to calculate the building's passive solar contribution. The energy balance equation is: Passive Solar Contribution = Total Heat Losses - Auxiliary Heat - Internal Gains]

In 1985, the passive solar research and development program was taken over by Energy, Mines and Resources. EMR spent more than $5.2 million over the last five years, providing the major impetus in developing passive solar technologies[11]. The major research work under EMR's project has concentrated on "market ready" product development and research activities. The heaviest emphasis of the program is on major improvements to the energy performance of windows. A window with a thermal insulation value of RSI 1 - a 300 per cent improvement over conventional double glazed windows - has been established by EMR as a performance target. To help industry attain those projected savings, approximately sixty per cent of the research budget is being spent in the area of high performance windows.

In 1986, Concordia University at Montreal had developed a unique way of impregnating gypsum drywall with a thermal phase change material (PCM). The addition of PCM to commonly used 1/2 inch thick gypsum wallboards increases the heat storage capacity from 35 kJ/m^2 to 317 kJ/m^2 - about 9 times[12]. The thermal storage capabilities of the modified gypsum wallboards can store and release solar gains or heat gains through the space heating system. The major benefit of this PCM wallboard technology would be seen in the air conditioning dominated regions, where the reduction in electricity consumption as well peak demand would result in greater energy savings. Currently, a major gypsum wallboard manufacturer is exploring the market for implementing the PCM wallboard technology on a commercial scale.

The passive solar research activities also helped in development of computer design and analysis tools, integrated mechanical systems and daylighting applications in commercial buildings.

Apart from the federal government funded projects, several universities, provincial ministries, consulting engineering and architectural firms and, most importantly, builders have contributed substantially to further the passive solar design approaches into main stream building construction.

2.3 Discussion on Canadian Achievements

The Canadian research efforts have led to the following rules of thumb for achieving a no-cost 20 to 25 per cent solar contribution:

- 8 to 10 per cent of floor area in windows, oriented within plus or minus 15 degrees of south
- forced-air heating systems to distribute solar gains
- conventional building materials to provide thermal storage
- low-energy construction techniques to reduce energy loads

Research into direct gain, indirect gain and isolated gain systems has produced a clear conclusion that in Canada direct-gain systems make the most sense. Cost-effective passive solar design for Canadian houses now calls for emphasizing high thermal resistance windows and low-energy construction practices.

With existing technology, the optimum south-facing window area is typically 8-10 per cent of the building's hardwood floors, and ceramic tile) will provide adequate thermal storage, while overheating and overcooling will be avoided. Larger south window areas can be used, but costs are higher for the extra windows, extra mass and extra distribution required, and overheating, glare, overcooling and increased purchased energy consumption can result unless great care is taken in the design stage.

Important conclusions have sprung from the wide participation in research and development activities. We have learned that passive solar strategies make most sense once heating and cooling loads have been reduced through different conservation technologies. So passive solar utilization is more beneficial in a better insulated house. A key Canadian energy conservation initiative in residential buildings has been the R-2000 program. The R-2000 program demonstrated that, on average 20 to 25 percent solar energy contribution to total heating energy can be achieved for the residential houses built to R-2000 construction standards.

The energy performance of any passive solar/low energy house is dependent on how the occupants use it. Studies carried out on similar families in identical houses have shown energy consumption rates can vary by a factor of two. Some responsibility is required on the part of the user to keep energy consumption low and the solar contribution high.

2.4 Studies of Passive Solar Potentials

There have been some earlier attempts to quantify the passive solar potential in buildings. One such survey presented to Energy, Mines and Resources in 1978[13], showed a passive solar contribution of 155 PJ in 1977 and predicted the future solar contribution potential of more than 320 PJ in the year 1995. However, a review of the calculation methodology showed some unrealistic assumptions: (1) the calculation for the passive solar contribution in the year 1977 was based on highly exaggerated housing stock -- the difference between published housing stock data and the study's data was more than 28 per cent; (2) more than fifty percent of future housing stock would have south orientation; (3) each house would have at least twenty-five to forty percent solar contribution (direct gain) toward heating requirements; and (4) predictions were based on other unrealistic scenarios. This study was largely ignored because of its deficiencies.

A comprehensive review of solar research and development priorities and program planning was carried out by the Solar Energy Program of the National Research Council Canada, in 1980. The ranking of the solar applications in order of their *contribution to energy objective* (CEO), showed that passive solar applications had the best CEO-cost ratio of all measures toward meeting building space heating requirements.

As a follow-up to the above recommendation to exploit passive solar potential in Canada, a detailed five year R&D plan was prepared by Con-Serve Group in cooperation with Scanada Consultants[14], for the National Research Council of Canada. This was perhaps the first *realistic* R&D planning attempt in developing the major source of renewable energy in Canada. Highlights of the R&D Plan were:

- development of direct gain, enhanced direct gain and isolated gain passive solar systems;
- development of a cost-effective, insulated window-shutter combination unit;
- development of sunspace packages;
- compilation of weather data and development of short term and long term design tools;

3. ASSESSMENT OF PASSIVE SOLAR POTENTIAL

The passive solar potential is assessed using the definition of passive solar as a net solar contribution to the building energy requirements. Existing residential building and non-residential building stock data are used to determine the solar contribution. The potential energy benefits have been assessed for four building sectors:

- Existing Residential (to 1988)
- New Residential (1989 - 2010)
- Existing Non-Residential or Commercial (to 1988)
- New Non-Residential or Commercial (1989 - 2010)

3.1 Building Stock Data

The housing stock data from the CMHC-2 model[15], developed by Scanada Consultants and enhanced to suit this project, was utilized in assessing the passive solar potential. The residential stock consists of single homes, semi-detached, row, walkups, and highrise buildings. There are 9.69 million residential units comprising 1,021 million m^2 floor area. The aggregate existing housing stock data compared well with the Energy, Mines and Resources Canada's Inter-Fuel Substitution Demand Model[16]. IFSD statistics shows 9.73 million units.

The non-residential building stock consist of offices, retail stores and malls, schools, warehouses, factories and plants, hotels, garage and service stations, recreational, churches and hospitals. The non-residential building stock data was developed based on Statistics Canada's statistical data on Fixed Capital Flows and Stocks[17] and Construction in Canada[18]. It is estimated that there are 0.59 million units comprising 573 million m^2 floor area. Both the residential and non-residential building stock data agreed within 7% with the energy consumption levels as shown in Statistics Canada's Report on Energy Supply-Demand[19], as explained in the later section of this report. The Statistics Canada's energy consumption data was lower.

The new residential building stock (1989-2010) is projected on the basis of net increase in the stock using the historical growth rates of the last twenty years. These projections also account for the replacement of "old and unusable" housing stock. In 2010, the residential stock would be 13.8 million units. The increase in the residential building stock would be 4.11 million units (479 million m^2 floor area) by the year 2010. The IFSD model predicts a housing stock of 13.1 million units, an increase of 3.37 million units by the year 2010. The difference in these projections is mainly due to the economic assumptions. As per our interpretation, this difference in building stock growth will not make a significant difference in the overall analysis. Figure 1 shows the comparison between IFSD and Scanada's projections to the year 2010. Both these projections are in close agreement up to the year 1994 and there is a difference of 2% by the year 2000 and about 5% by the year 2010. Scanada's projection for the year 2010 is higher than IFSD.

The new non-residential building stock data was projected using the net increase in the stock using the historical growth rates for different types of commercial buildings. The projected commercial building stock in 2010 would be 0.89 million units or 858 million m^2. The increase in the non-residential stock would be 0.3 million units or 285 million m^2 floor area by the year 2010.

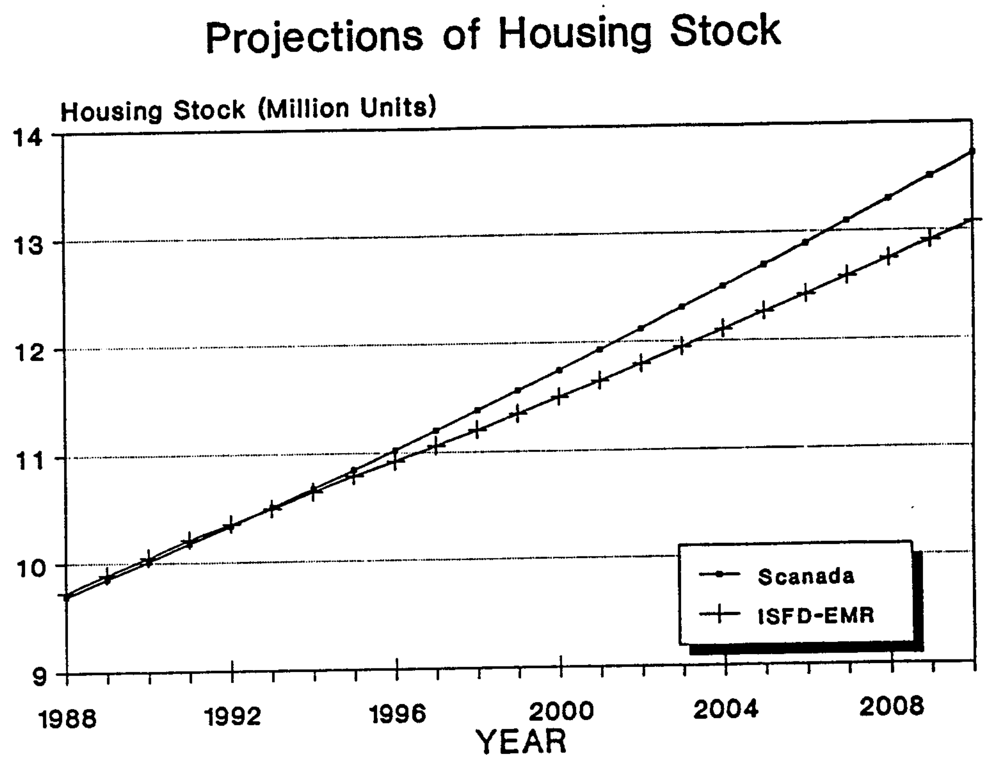


Figure 2: Projection of Housing Stock by the Year 2010.

3.2 Assessment Methodology

Assessing the energy conservation potential of passive solar technologies is based, firstly, on a reconstruction of current energy consumption levels for each province and building sector using a "building stock model" approach. Stock numbers and energy consumption levels developed in this model are compared to other available statistics to improve the confidence levels of the estimates. The assessments of conservation potential are developed using the following steps. For each building sector, the following numbers are determined from statistics or estimated based on assumptions or methods recorded in Appendix A:

- the building stock
- the numbers and sizes of the relevant building assemblies

- the current Energy Performance Index (EPI) for those assemblies
- the technologies that can improve the assembly EPI
- the ultimate EPI for those assemblies
- the overall stock performance with the ultimate EPI
- the technically feasible (achievable) EPI
- the overall stock performance with the technically feasible EPI.

Once these calculations are performed, scenarios of reasonably achievable conservation targets are developed based on the estimation of the technically feasible potential. Therefore, this methodology yields three levels of estimates of conservation potential in existing building stock and new construction:

- **ultimate potential** - a maximum probable conservation potential that would be realized if all technologies were developed to the fullest and applied universally. This potential represents an upper limit. For example, windows with thermal resistance of RSI 1.8 and shading coefficient of 0.5 were used in retrofitting all existing buildings, and in all new construction.

- **technically feasible potential** - a conservation potential that could be achieved if all currently available and clearly emerging technologies were applied universally. For example, technically feasible and currently available windows (RSI 1.0) were used universally in retrofitting the existing building stock and in new construction.

- **reasonably achievable market potential** - developed by postulating scenarios of market penetration of available and clearly emerging technologies. The 100% market penetration rate is equivalent to the "technically feasible potential".

Most of the above steps involve simple information gathering or engineering calculations and estimations; however, a number of key assumptions are required to complete the estimation. These assumptions along with a description of the procedure are recorded in Appendix A. The estimation of passive solar contribution is an incremental potential in the existing residential and commercial buildings and new construction.

The methodology was implemented on four database spreadsheets, one for each building sector. The results of the calculations are reproduced in Appendices **B** through **E**. A summary of the approach and results for each sector is described below.

3.3 Passive Solar Energy Contribution in Existing Buildings

In the existing building stock the solar energy transmitted through windows, at a varying degree, contributes in the space heating energy requirements during heating season. The passive solar energy contribution in existing buildings is estimated here as the solar energy transmitted through windows alone. This estimation does not include the heat losses through windows. Four different types of buildings (single home, semi-detached house, apartment building and office building) were simulated using the building energy analysis computer program in eight different locations. The solar energy contribution in these buildings was taken as a base and projected for the whole building stock.

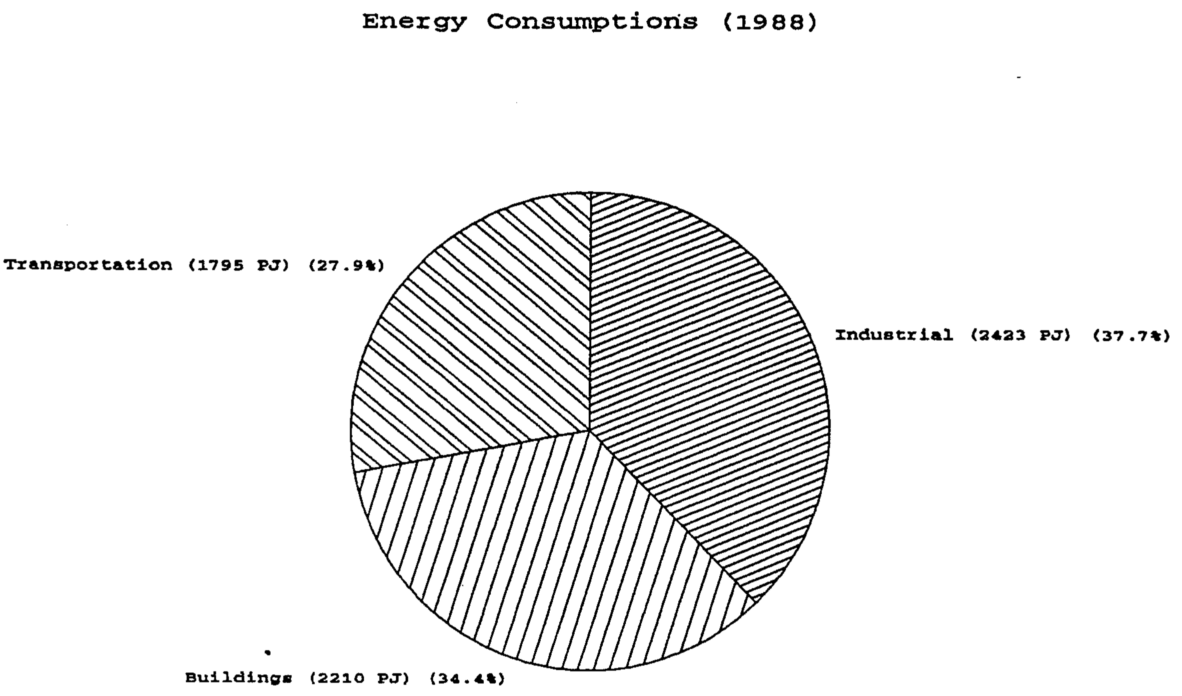


Figure 3: Energy Consumptions in Major Sectors in Canada (1988).

There are 9.69 million residential units in Canada, in the year 1988, comprising 1,021 million m^2 floor area. The analysis of existing residential building stock shows a passive solar contribution of 37.1 PJ/year in space heating requirements. The existing non-residential building stock consists of 0.59 million units consisting of more than 573 million m^2 floor area. In the non-residential building sector, passive solar contributes 11.4 PJ/year in building space heating requirements. Thus, the passive solar contribution toward meeting building energy requirements is 48.5 PJ/year in the year 1988. The passive solar contribution of 48.5 PJ/year in existing buildings should not be compared with the estimation of passive solar potential as shown in following sections.

In Canada, using the IFSD energy consumption data for the year 1988, the building sector accounts for approximately 34% of the total energy requirements. Figure 2 shows the energy requirements for three major sectors, namely, buildings, industrial and transportation in 1988. Passive solar contributes about 4.4% of the total building space heating energy requirements, as is shown in Figure 3.

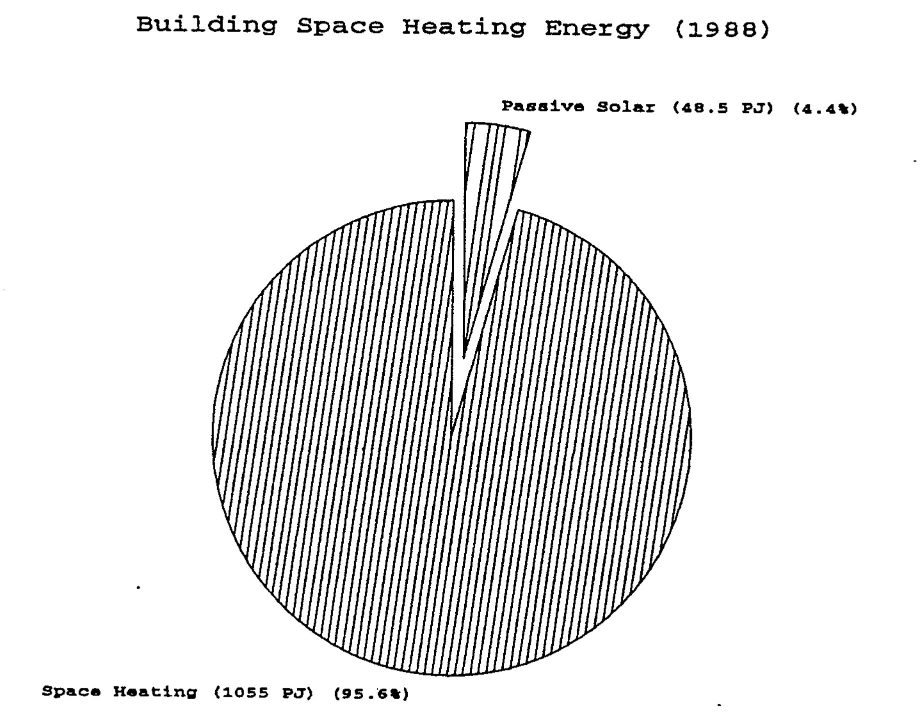


Figure 4 Passive Solar Contribution to Space Heating in Existing Buildings.

3.4 Residential Sector - Retrofit Potential [illegible]ing Stock

The single technology that can clearly be applied to existing dwellings to improve energy performance is high thermal performance window technology. Ultimately, all windows are replaceable. This fact, combined with the major advances in thermal performance of windows in recent years, both in terms of effective R-value and of airtightness of the window assembly, makes this technology extremely attractive for upgrading the energy performance of the solar aperture of virtually all existing dwellings. A detailed analysis is shown in Appendix B.

The estimated 133 million square meters of glass area in Canadian houses currently lose a net of 105 PJ in energy per year. This represents over 11% of the nation's residential space heating bill. High performance window technologies, if developed to their fullest and applied to all windows in today's stock could turn this net loss into a net gain of 191 PJ - a gain that would displace the losses from other components of buildings. Thus, the ultimate potential saving would be almost 296 PJ for this technology (with RSI 1.8). A technically achievable potential using today's best available window technology (RSI 1) could also turn the window aperture into a "net gainer" for the nation, that is, about 31 PJ of net gain. Therefore, the technically achievable conservation potential, as applied to existing houses and apartments, is 136 PJ/year (i.e., 105 +31). This represents a 13% saving in current levels of annual consumption for space heating.

The provincial distribution of this "achievable conservation potential" is shown in Table 3.1. Ontario and Quebec are key areas of conservation potential because of their large housing stock and because of considerable incident solar energy. The prairie provinces also show fair collection potential because of the colder climate and good solar availability. The eastern provinces have less housing stock, less available incident solar radiation and a more moderate climate, resulting in a smaller savings potential for that region. Alberta and British Columbia shows greater potential due to higher solar insolation and larger housing stock.

Table 3.1: Existing Residential (Retrofit Potential) in the Year 2010

Province	Ultimate Passive Solar Potential (PJ/Year)	Technically Feasible Potential (PJ/Year)
Newfoundland	5	2
Prince Edward Island	1	1
Nova Scotia	8	4
New Brunswick	7	3
Quebec	65	31
Ontario	110	46
Manitoba	17	8
Saskatchewan	18	9
Alberta	38	19
British Columbia	27	13
Total	**296**	**136**

3.5 Residential Sector - New Construction

Three of the four promising technologies identified in the introduction can be applied to new residential construction: (1) high performance windows, (2) thermal storage, and (3) integrated mechanical systems. Virtually all new houses and apartments can currently be built with these new technologies to make them more efficient users of solar energy.

An estimated 4.13 million new housing units by the year 2010 built at today's National or Provincial Building Code would consume 327 PJ annually by the year 2010 without the benefit of improved passive solar technologies.

The estimated 72 million square meters of new glass area to be built in Canadian houses by the year 2010 would lose a net of 21 PJ/yr in that year. This would represent over 6% of the space heating bill for the new stock in 2010. New window technologies, if developed to their fullest and applied to all new residential construction could turn this net loss into a net gain of 93 PJ. Thus, the ultimate potential saving for high performance windows would be 114 PJ/yr for this technology (i.e., 93+21). Thermal storage and integrated mechanical systems could increase this potential saving by another 37 PJ/yr, for a total ultimate potential of 151 PJ/yr in the year 2010. (The detailed assessment of thermal storage and integrated mechanical systems is given in the Section 4.) A detailed analysis is shown in Appendix C.

A technically achievable potential using today's best available windows (RSI 1) could also turn the new residential stock into a "net gainer", that is, about 21 PJ of net gain. Therefore, a technically feasible potential for this technology, as applied to new houses and apartments, is 42 PJ (i.e., 21+21). This represents a 13% saving in projected levels of consumption for space heating that would occur with the penetration of high performance windows in the new housing market. Full penetration /of phase-change material (PCM) storage and integrated mechanical system (IMS) technologies would increase this potential to 53 PJ or 15% savings in projected consumption levels.

The provincial distribution of this technically achievable conservation potential is shown in Table 3.2. Here Alberta joins Ontario and Quebec as a key area of conservation potential because of its large predicted rate of growth in housing stock and because of its good incident solar energy.

Table 3.2: New Residential - Passive Solar Potential in the Year 2010.

Province	Ultimate Passive Solar Potential (PJ/Year)	Technically Feasible Potential (PJ/Year)
Newfoundland	2.6	0.9
Prince Edward Island	1	0.2
Nova Scotia	3.9	1.1
New Brunswick	2.6	0.9
Quebec	30.3	11
Ontario	49.3	15.3
Manitoba	5.3	2
Saskatchewan	9	3.7
Alberta	34	13.1
British Columbia	13	5
Total	**151**	**53.2**

3.6 Non-Residential or Commercial Sector - Retrofit Potential in Existing Stock

The main passive solar technology that can be applied to existing commercial buildings is, again, high performance window technology. The estimated 64 million square meters of glass area in Canadian commercial buildings currently lose a net of 81 PJ in energy per year. This represents over 18% of the nation's commercial building space heating budget. New window technologies, if developed to their fullest (RSI 1.8) and applied to all non-residential windows could turn this net loss into a net gain of 77 PJ/yr. Daylighting retrofits in existing in building can contribute up to 14 PJ/yr by the year 2010. Thus, the ultimate potential saving would be almost 172 PJ/yr. (The detailed assessment of daylighting is given in the Section 4.) A detailed analysis is shown in Appendix D.

A technically achievable potential using today's best available window technology (RSI 1) could also turn the window aperture into a "net gainer" for the nation, that is, about 11 PJ of net gain for a savings of 92 PJ/yr. As well, high performance windows in commercial buildings would save an additional cooling requirement of almost 5 PJ/yr, for a total potential of 97 PJ/yr. Daylighting retrofits in existing buildings would add 3 PJ/yr, making the total conservation potential of 100 PJ/yr. This represents about 21% of the annual energy use for space heating and cooling of commercial buildings in 1989. The provincial distribution of this "technically feasible conservation potential" is shown in Table 3.3.

Table 3.3: Existing Commercial (Retrofit Potential) in the Year 2010.

Province	Ultimate Passive Solar Potential (PJ/Year)	Technically Feasible Potential (PJ/Year)
Newfoundland	3	2
Prince Edward Island	0	0
Nova Scotia	3	3
New Brunswick	4	3
Quebec	41	24.5
Ontario	60	33
Manitoba	15	6.1
Saskatchewan	10	6.1
Alberta	20	13.3
British Columbia	16	9.1
Total	**172**	**100**

3.7 Non-Residential or Commercial Sector - New Construction

Three promising technologies identified in the introduction can be applied to new commercial construction: high performance windows, thermal storage, and daylighting.

Integrated Mechanical Systems for new commercial buildings is a technology that is already viable and well applied. Thus this technology falls outside the scope of this work for these buildings. Virtually all new commercial buildings can currently be built with these new technologies to make them more efficient users of solar energy. An estimated 285 million square meters of new commercial space by the year 2010 built at today's standards would reduce 256 PJ annually by the year 2010 with the benefit of improved passive solar technologies. Detailed assessment of emerging passive solar technologies is given in Section 4. A detailed analysis is shown in Appendix E.

The estimated 32 million square meters of new glass area to be built in Canadian commercial buildings by the year 2010 would lose a net of 30 PJ/yr in that year. This would represent over 13% of the space heating bill for the new stock. New window technologies, if developed to their fullest and applied to all non-residential windows could turn this net loss into a net gain of 50 PJ. Thus, the ultimate potential saving for RSI 1.8 windows would be 77 PJ. Thermal storage and daylighting systems could increase this potential saving by another 31 PJ/yr, for a total ultimate potential of 108 PJ/yr in the year 2010.

Table 3.4: New Commercial Potential in the Year 2010.

Province	**Ultimate Passive Solar Potential (PJ/Year)**	**Technically Feasible Potential (PJ/Year)**
Newfoundland	1.1	1.0
Prince Edward Island	1.0	0.4
Nova Scotia	2.3	2.0
New Brunswick	3.0	1.6
Quebec	24.4	17.0
Ontario	36.6	23
Manitoba	4.5	3.0
Saskatchewan	5.7	4.1
Alberta	19.3	15
British Columbia	10.0	6.8
Total	**108**	**74**

A technically achievable potential using today's best available windows (RSI 1) could also turn the new non-residential window areas into a "net gainer", that is, about 9 PJ of net gain for a savings of 39 PJ/yr. Another 2 PJ would be saved in cooling energy by the same measure. Therefore, a technically feasible potential for this technology as applied to new commercial buildings is 41 PJ. This represents a 16% saving in projected levels of consumption for space heating in this sector. Full penetration of PCM storage and daylighting technologies would increase this potential to 74 PJ/yr, or 29% savings in projected consumption levels.

The provincial distribution of this "technically feasible conservation potential" is shown in Table 3.4. Ontario, Quebec, Alberta and British Columbia are key provinces of large potential.

3.8 Summary of the Assessment of Passive Solar Potential

The solar contribution in existing residential and non-residential building is 48.5 PJ/year, which is 4.4% of total space heating energy requirements in 1988.

The passive solar contribution in the existing building stock is considered as a reference for estimating the future passive solar potential. The estimation of passive solar potential is based on the "net" (energy balance of solar gains and heat losses) energy conservation effect in reducing the auxiliary heating, lighting or cooling energy requirements. The assessment of passive solar technologies provides estimation of incremental passive solar potential in meeting the building energy requirements.

In total, a 363 PJ/yr contribution in the year 2010 has been identified as a technically feasible energy conservation target for current and emerging passive solar technologies. The distribution of this potential shown in Table 3.5.

Table 3.5: Estimate of the Passive Solar Conservation Potential in Canada. Technically Feasible Potential by the Year 2010. (PJ/Year).

Technology	Residential Stock		Commercial Stock		**Total (PJ/Year)**
	Existing	New	Existing	New	
High Thermal Performance Windows	136	42	97	41	**316**
Daylighting	-	-	3	31	**34**
Integrated Mechanical Systems	-	10	-	-	**10**
Thermal Storage	-	1	-	2	**3**
Total	**136**	**53**	**100**	**74**	**363**

4. TECHNICAL AND ECONOMIC ASSESSMENT OF PASSIVE SOLAR TECHNOLOGIES

Assessment of passive solar potential on an aggregate building stock has shown a tremendous potential of reducing the building energy requirements by 363 PJ/year in the year 2010. Passive solar potential can be achieved through the use of the following emerging passive solar technologies:

- High Thermal Performance Windows,
- Daylighting,
- Integrated Mechanical Systems, and
- Thermal Storage using Phase Change Materials.

These technologies can be further evaluated and assessed on the basis of their technical feasibility, energy savings potential and economic viability. Scenarios are presented here to show the impact of different uptake rates of these passive solar technologies.

4.1 Case Study on High Thermal Performance Windows

4.1.1 Background

Windows play a significant role in improving quality of life, comfort and indoor environment in buildings. Like many parts of the building envelope, a window separates conditions between inside and outside, with the added benefit that it can be operable and to a large degree transparent to natural light. Windows are indeed an important part of passive solar design features which integrate the collection, distribution and storage of solar energy into the design of the building itself. It has been established that for new houses, the integration of passive solar concepts in the building design require no extra costs to achieve a solar contribution to the heating load of approximately 25 percent.

In a typical house with moderate insulation levels, standard double glazed windows account for about 23 per cent of the total heat loss. As the envelope insulation is increased, windows become the single largest source of heat loss at more than 34 per cent of the total; however, the amount of heat losses through the windows remain the same. Also higher interior pane temperatures are required to avoid one of the major problems with windows: excessive condensation, and the deterioration it causes, as the humidity rises in tighter homes.

This case study has been undertaken to review and analyze the economic viability and future potential of passive solar energy with the use of new, innovative high performance windows in residential and commercial buildings. Scenarios are presented here to show the impact of different uptake rates of windows for the retrofit market.

4.1.2 Thermal Analysis

The thermal performance data for some of the commercially available windows are presented here to show the availability of windows with high thermal resistance. Table 4.1 presents heat loss coefficients for the centre portion of the glazing, for the entire glazing unit, and for the total window, for three different types of spacer in the same wood-frame window[20]. An aluminum spacer is the conventional product. The butyl-metal spacer has been available for several years and now holds perhaps more than 25 percent of the Canadian market. The insulated spacer is a silicone foam product now available in the market. In the table, it is assumed that all glass uses the Canadian-made sputtered (or "soft") coating to offer an emissivity of only 0.09. Table 4.1 shows the thermal performance for ASHRAE winter design condition (outdoor temperature of -18 C, wind speed of 6.6 m/s; and indoor temperature of 20 C).

Table 4.1: Window Thermal Performance of Wood Frame Windows with a 12.7 mm Spacing

Glazing Type	RSI-Value (m^2K/W)		Shading Coeff.	Solar Trans		Inner Glazing Temp (C)
	Centre	Window		Solar	Visible	
1. Standard Double, air filled						
Aluminum Spacer	0.36	0.36	0.89	0.70	0.81	7.4
Butyl-Metal Spacer	0.36	0.37				
Insulated Spacer	0.36	0.38				
2. Double, Low-E, 12.7mm, air filled						
Aluminum Spacer	0.56	0.47	0.74	0.57	0.74	12.2
Butyl-Metal Spacer	0.56	0.50				
Insulated Spacer	0.56	0.52				
3. Double, Low-E, argon filled (Super Double)						
Aluminum Spacer	0.70	0.52	0.74	0.57	0.74	13.9
Butyl-Metal Spacer	0.70	0.55				
Insulated Spacer	0.70	0.59				
4. Standard Triple, air filled						
Aluminum Spacer	0.56	0.47	0.79	0.60	0.74	12.1
Butyl-Metal Spacer	0.56	0.49				
Insulated Spacer	0.56	0.52				
5. Triple, Low-E, argon filled (Super Triple)						
Aluminum Spacer	1.26	0.70	0.58	0.43	0.61	17.2
Butyl-Metal Spacer	1.26	0.76				
Insulated Spacer	1.26	0.84				

Indoor thermal comfort during the winter is affected by the presence of large cold surfaces, such as windows, which contribute to discomfort through direct radiant heat from the occupant to the cold surface. As shown in Table 4.1 as the thermal resistance of the glazing unit is increased, the warmer the inner glazing becomes. This in turn allows higher indoor relative humidity to be maintained without excessive condensation on the glass. However, because the frame and edge heat loss are higher than the centre glazing, their temperatures will be colder. The edges will thus experience condensation earlier, reducing the allowable indoor relative humidity levels. Presently research is underway to allow better prediction of frame and edge temperatures and attendant condensation.

Presently a high-performance glazing unit (triple glazed, low-E, argon filled, and wood-vinyl frame) with a centre glazing RSI 1.25 (R 7.1) and an <u>overall</u> thermal resistance of RSI 0.96 (R 5.5) is available in the market. This is getting close to the industry's target of RSI 1.25-1.40 (R 7-8) and a shading coefficient of 0.5. Such a window would be a net gainer of energy in any location in populated Canada, even in north facing orientations. As the window becomes a net gainer, it can bestow remarkable benefits on whole-house economics.

4.1.3 Energy Savings Potential of High Thermal Performance Windows

The energy analysis of high thermal performance windows provides a measure for the economic viability based solely on the energy savings potential. The reduction in heating and cooling energy depends on orientation, location, and utilization of solar gains. In the present analysis, the effects of window orientation and solar energy utilization factors were eliminated by performing the annual energy analysis for twenty different types of houses[21]. The reductions in the energy savings were then averaged on the basis of total window area. The averaging procedure allows the energy savings to be related to only two factors: the location, and the cost of energy.

The energy savings potential of different types of windows were calculated using the standard double glazed window as a reference. The incremental energy savings are used in the economic analysis. The utility rates of electricity and natural gas were obtained from Utility Rate Survey for the year 1989[22]. Table 4.2 shows the average energy savings per square metre of window in different locations across Canada. Table 4.3 shows the cost savings per square metre of window with electric heat and cooling.

Table 4.2: Average Annual Space Heating and Cooling Energy Savings per Square Metre of Window

City	Energy Savings Potential (kWh/m²/Year)			
	Standard Double	Super Double	Standard Triple	Super Triple
Halifax	Base	143	81	167
St.Johns	Base	160	90	195
Quebec City	Base	166	96	198
Montreal	Base	148	86	180
Ottawa	Base	150	87	188
Toronto	Base	135	81	165
Winnipeg	Base	188	106	224
Saskatoon	Base	192	108	228
Edmonton	Base	192	107	232
Vancouver	Base	128	73	155
Canada	**Base**	**161**	**91**	**193**

Table 4.3: Average Annual Electric Space Heating and Cooling Dollar Savings per m² of Window.

City	Fuel Cost (c/kWh)	Dollar Savings Potential ($/m²/Year)			
		Standard Double	Super Double	Standard Triple	Super Triple
Halifax	6.46	Base	9.19	5.23	10.78
St. Johns	6.06	Base	9.70	5.45	11.82
Quebec City	4.26	Base	7.07	4.09	8.43
Montreal	4.26	Base	6.30	3.66	7.67
Ottawa	6.20	Base	9.30	5.39	11.66
Toronto	6.36	Base	8.59	5.15	10.49
Winnipeg	3.84	Base	7.23	4.07	8.62
Saskatoon	5.26	Base	10.09	5.68	11.99
Edmonton	5.44	Base	10.44	5.88	12.62
Vancouver	4.54	Base	5.81	3.32	7.04
Canada	**5.37**	**Base**	**8.48**	**4.80**	**10.17**

Table 4.4: Average Annual Space Heating and Cooling Dollar Savings per Square Metre of Window - Heating with Natural Gas and Cooling with Electricity

City	Fuel Cost ($/GJ)	Dollar Savings Potential ($/m²/Year)			
		Standard Double	Super Double	Standard Triple	Super Triple
Halifax	---	Base	---	---	---
St. Johns	---	Base	---	---	---
Quebec City	6.65	Base	6.94	4.01	8.27
Montreal	6.65	Base	6.18	3.59	7.50
Ottawa	5.14	Base	5.23	3.10	6.56
Toronto	5.32	Base	5.14	3.03	6.20
Winnipeg	3.22	Base	4.14	2.29	4.74
Saskatoon	3.80	Base	5.09	2.81	6.01
Edmonton	3.51	Base	4.81	2.59	5.63
Vancouver	4.18	Base	4.05	2.34	4.93
Canada	**5.37**	**Base**	**5.19**	**2.97**	**6.23**

As shown above, the energy savings obtained through the use of high thermal performance windows varies with the location and the cost of energy. For example, Winnipeg has higher heating degree days hence higher energy unit savings; however, the dollar savings in Toronto are higher due to fuel costs. The difference between the cost of electricity and natural gas also plays an important factor in the determination of economic benefits of the high thermal performance windows.

4.1.4 Economic Analysis

The economic analysis is intended here to serve as a means for determining the initial energy conservation investment required to meet certain economic conditions. The result of economic analysis depends on the assumptions of economic factors, such as annual inflation rate and fuel price escalation rate.

Maximum Initial Conservation Investment:

The maximum incremental investment calculation determines the extra amount of capital one should be willing to invest to pay for itself during the selected payback period. The incremental energy savings of high performance windows in comparison to standard double glazed window for the first year were used in determining the extra amount of capital warranted in choosing a high performance window.

Table 4.5 presents the results of the economic analysis with the following assumptions:

1. annual fuel escalation rate is 8 per cent, which is an average of suggested rates of 6 and 10 percent
2. annual inflation rate is 4.5 per cent, which is the current inflation rate

Table 4.5: Maximum Initial Conservation Investment Calculations.

$ Energy Savings ($/m^2)	Pay Back Period (Years)				
	2	3	5	7	10
	Break Even Investment ($/m^2)				
2.00	3.23	4.51	6.56	8.04	9.44
4.00	6.46	9.02	13.12	16.08	18.88
6.00	9.66	13.56	19.68	24.12	28.32
8.00	12.88	18.08	26.24	32.16	37.76
10.00	16.10	22.60	32.80	40.20	47.20
12.00	19.32	27.12	39.36	48.24	56.64

For example, the use of a "super double" - a window with low-e coating, argon gas filled, and butyl-metal spacer in wood frame - instead of a conventional double glazed window will save $8.59 per square metre of window every year for electrically heated home in Toronto. If the house is heated with natural gas then the energy savings will be $5.14 per square metre of window every year. On an average, a 200 square metre house will avoid $150-$270 every year in space heating and cooling bill alone. With these energy savings figures for the first year, one can easily determine the maximum initial incremental investment in windows for a given payback period. Such analyses are shown in Figure 4 and 5 for the maximum initial incremental investment needed for the "super double" or "super triple" window within a prescribed payback period.

Recent window costing data provided by a manufacturer of high quality windows shows that the window buyer would have to pay an additional cost of $24 per square metre of window for a soft low-e coated, argon filled window compared to a standard double glazed window[23, 24]. With current fuel costing data, the super double glazed window will pay the incremental investment back in less than 4 years for an electrically heated house; while for the natural gas usage for heating and electricity for cooling, it will take 8 years with the current cost data and economic conditions assumptions. With higher volume production, the cost differential might become much less substantial.

4.1.5 Analysis of Window Market and Potential Impact on Energy Savings - "Window Uptake" Scenario

There are approximately 1,200 window and glazing unit manufacturers in Canada. It is estimated that less than five per cent of these companies have fenestration product sales of more than 50 million dollars. These few large companies command approximately 70-80 per cent of the market[25, 26].

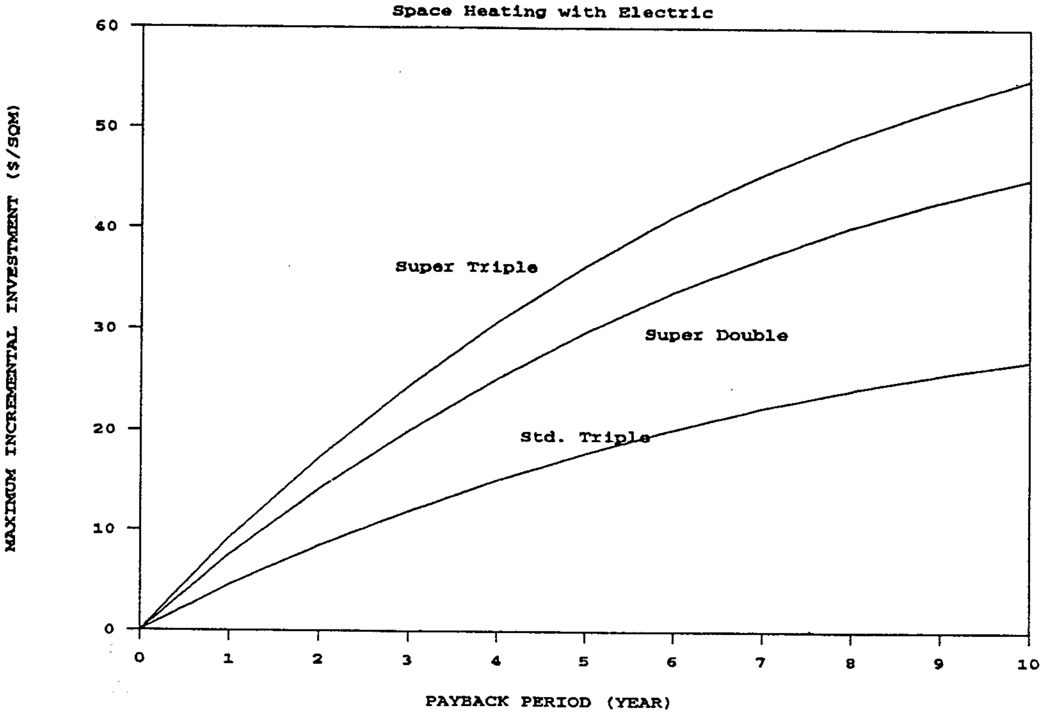


Figure 5: Maximum Initial Investment Calculations for Using High Performance Windows in Toronto with Space Heating and Cooling using Electric.

The window market in Canada has grown rapidly from 5.3 million m^2 in 1984 to a phenomenal 7.2 million m^2 in 1988. The market growth in window roughly follows the pattern of increasing construction activities during the same time period. Figures 6 and 7 show the summary of window sales and market segments in Canada during 1984-1988. The renovation market comprises the dominant component, at 52 per cent, while the new construction window market represents 32 per cent and commercial segment 16 per cent[27].

The regional market breakdown in 1988 shows that Ontario accounts for 39 per cent, Quebec 24 per cent, the West 22 per cent, and the Atlantic region 15 per cent of total window sales.

The established window market activity offers a good opportunity for promoting the high thermal performance windows. According to latest sales figures as published in the trade journals, sales of low-emissivity coated sealed glazing units comprise approximately five to seven per cent of the total sales in the year 1987, compared to well below one per cent in 1984. The projected annual market for the low-E coated windows by 1992 is 20 to 25 per cent of total sales[28]. Figure 8 shows the projections in the increase of high thermal performance windows in the new construction market in residential buildings. As shown, in new residential buildings high thermal performance window market would increase from 7% in 1990 to a 67% in the year 2010.

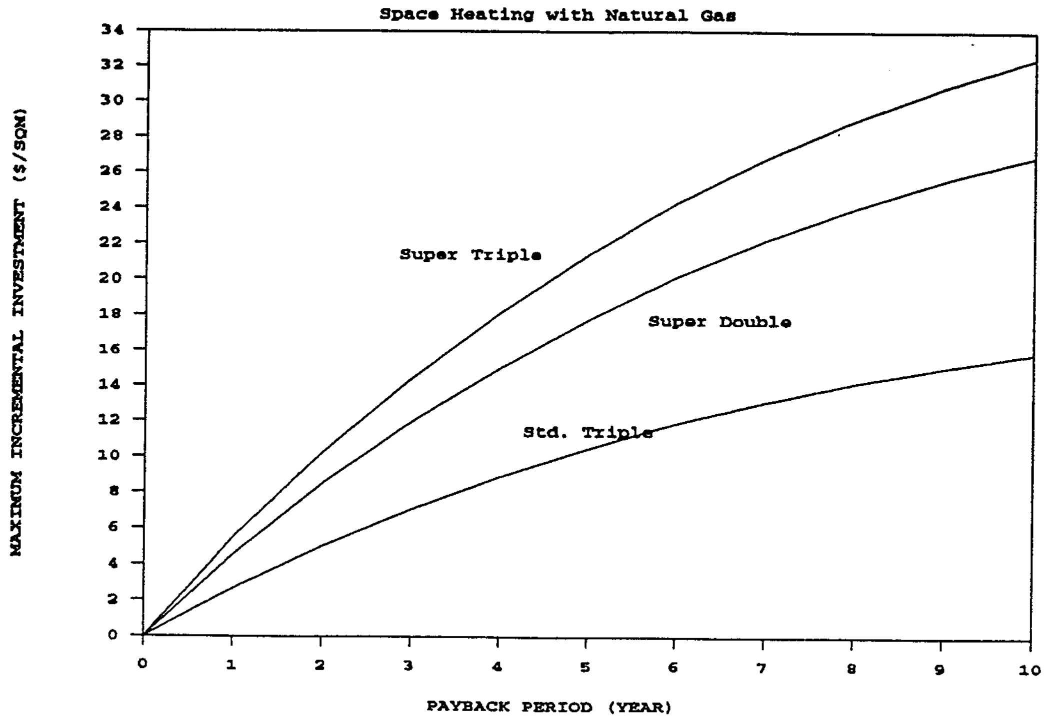


Figure 6: Maximum Initial Investment Calculations for Using High Performance Windows in Toronto with Space Heating by Natural Gas and Cooling by Electric.

A scenario is presented here to evaluate the impact of high thermal performance windows on the passive solar contribution. Current energy costs, window technology, economic indicators and distribution of window market were assumed.

Scenario: Projections Based on Assumed Market Penetration

Table 4.6 shows the impact of market penetration of high thermal performance windows and the increase in the passive solar contribution. A recent window market survey projects an average 4.5% annual increase in the window market in the United States during the next 10 years and 3.5% increase thereafter[29]. A comparable growth rate has been assumed for the Canadian market.

The high thermal performance windows would contribute an additional 0.37 PJ/year[**] with a modest seven percent of total sales volume of 1990. A market share of 34% would provide 3.30 PJ/year at the end of Year 2000.

The cost savings (or *energy cost avoidance*) calculations show a potential savings of $5.5 million in 1990 with the use of electric space heating. Similar analysis with natural gas heating shows cost savings of $2.1 million

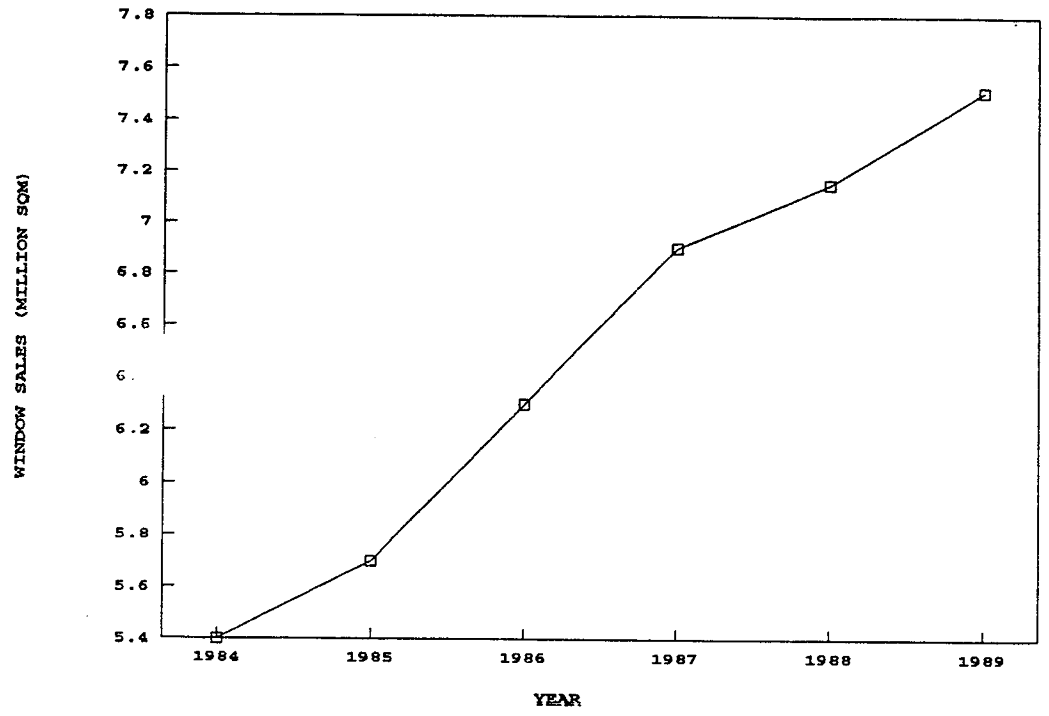


Figure 7: Window Market in Canada.

in 1990 with current cost data. In the year 2000, annual savings would be $49 million with electric heating and $19 million with gas heating, at today's fuel costs.

Calculations for Determining Passive Solar Contribution:

The energy savings of a low-E coated, argon filled window is given in the Table 4.2. The window market distribution is assumed to remain same as in 1988. Ontario: 39%, Quebec: 24%, West: 22%, and Atlantic: 15%. The passive solar contribution with full market penetration is given by,

$= 7.85 \text{ million} * [\, 0.39*171 + 0.24*182 + 0.22*216 + 0.15*178 \,] / 278 \text{ GJ}$

$= 5.21 \text{ PJ}$

The 7 per cent penetration of high performance windows in the total window market would provide:

$= 5.21 \times 0.07 = 0.37$ PJ/Year in the Year 1990.

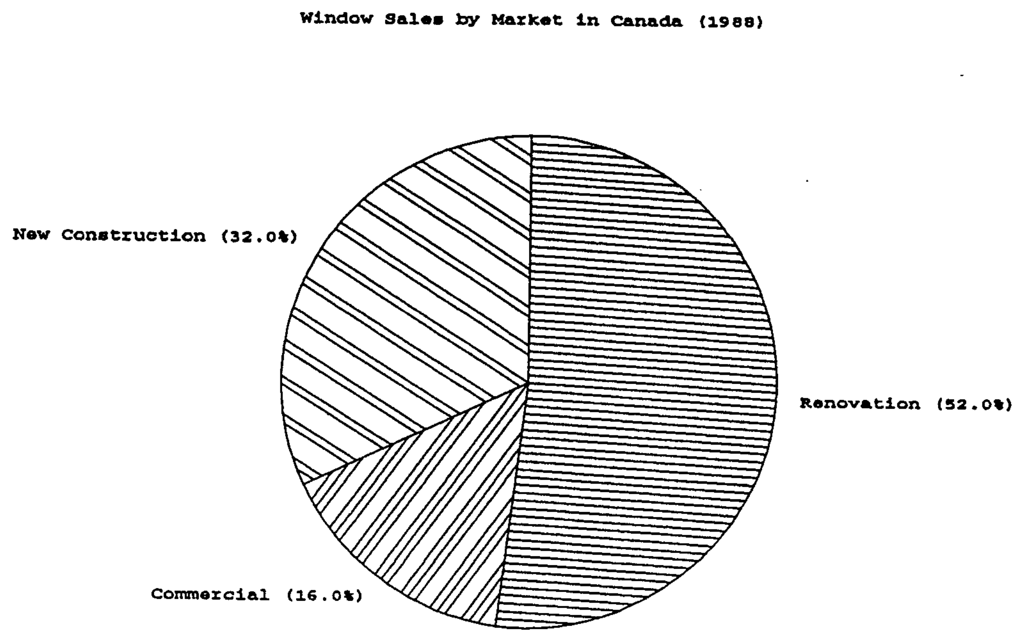


Figure 8: Window Sales - Segments (1988).

Table 4.6: The Passive Solar Potential of Currently Available High Performance Windows. Projections are based on 4.5% increase in the window market to year 2000 and 3.5% increase thereafter.

Year	Existing & New Window Market million m^2	Assumed Market Penetration %	Passive Solar Potential (PJ/Year)	Total Passive Solar Potential (PJ/Year)
1990	7.85	7	0.37	0.67
1995	9.78	14	1.11	4.44
2000	12.19	34	3.30	15.63
2005	14.48	48	6.19	41.14
2010	17.19	67	10.31	83.62

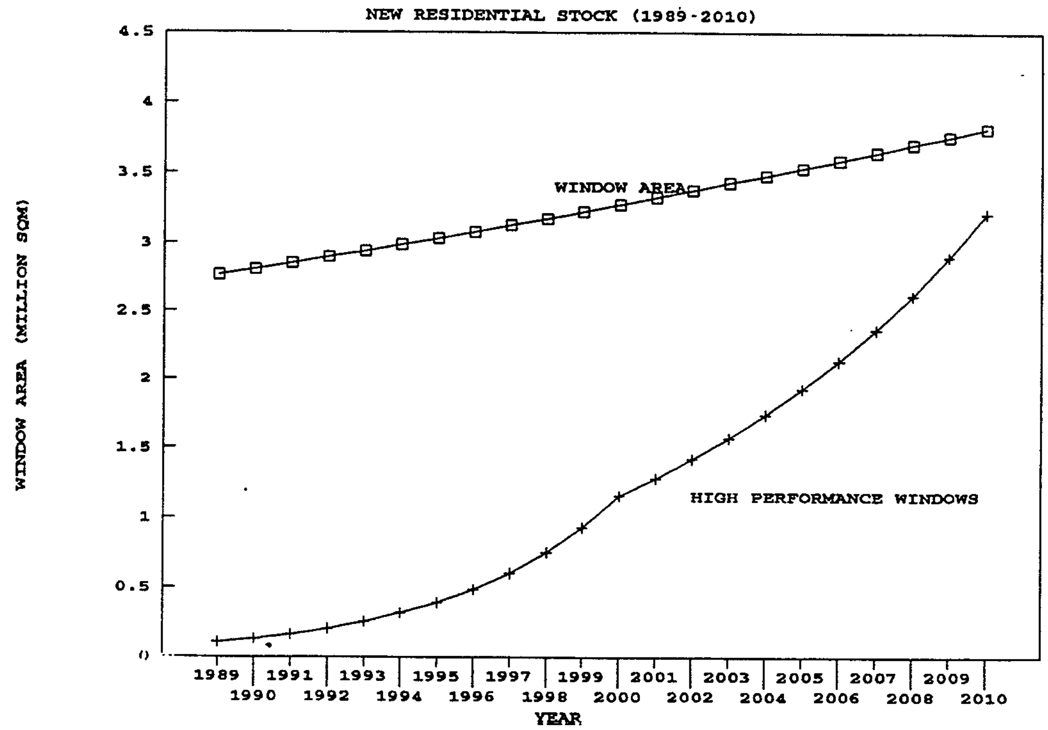


Figure 9: High Performance Window Uptake Scenario in New Residential Buildings (1989-2010).

Life Cycle Cost Analysis

A life-cycle cost analysis of the energy savings for the first year, on the basis of long term consistent performance, can show the potential impact of today's high thermal performance windows in the national economy.

The net life-cycle cost calculations assume that the general inflation rate is equal to the energy inflation rate. The average interest rate for the 10 year period is assumed to be 9 per cent while the inflation rate is assumed to be moderate 4.5 per cent.

Energy savings of $5.5 million in 1990 to $154 million in 2010 for the year can be gained from, respectively, 7% and 67% penetration of high performance windows. Each new year of window sales add to the savings total so that up to year 2010, the net present value savings in Canada would be $9,600 million.

4.1.6 High Performance Windows: Market Penetration Scenarios

The important facet of the new emerging window developments is that these technologies are now commercially available and rapidly improving in the field. Apart from energy savings, thermal comfort plays an important role in consumer preference for high performance windows. These factors play a major role in market penetration. However, without reliable market survey information it is difficult to assign cost values to these factors.

While energy efficiency continues to be a good sales pitch and a common sense approach, the underlying reason for the demand for high performance windows is perceived value and added "life-style" comfort, along with the general trend toward increasing renovation activity rather than new home construction. The current attitude in Canada towards improved insulation, high thermal performance windows, etc., has changed from one related to the conservation of energy, usually associated with cost savings, to one of comfort. Comfort is becoming more important to home-owners who can afford to pay for it. They want the benefit of large window areas in the winter without commensurately large heat losses. They want ease of operation and maintenance, attractive appearance, and, generally, the comfort factor is going to lead to the purchase of upgraded windows[30, 31].

The initial concerns regarding durability of high thermal performance windows are disappearing. A recent survey shows that the average life of low-emissivity coatings can be as high as 25 to 30 years. The gas filling can last for more than 15 years before appreciable loss in thermal performance. The more rigorous production process, which involves low-E coatings, gas filling and better spacer components, tends to ensure higher quality and better seal durability. Hence, high thermal performance windows may already carry a consumer warranty of 10 years compared to five years for a standard double glazed window.

Recently, ALUMI-NEWS - a Canadian magazine serving the window industry and renovation market - conducted an industry-wide survey on the selection aspects of windows for the renovation market. Survey results have shown the following consumer reasons for window replacement: (1) reduced maintenance 77%; (2) energy savings 65%; (3) added value to home 63%; (4) comfort 61%; and (5) Need Repair 51%. The economic opportunities for exploiting the use of high thermal performance windows in the house retrofit market are probably greater than for any other energy conservation measure at hand. The retrofit market tends to prefer high quality window products and is less sensitive to cost than in new construction. Windows in the replacement market are sold on the basis of their thermal comfort, freedom of maintenance, and appearance.

4.1.7 Regional Implications

There are regional differences in the energy costs and the heating or cooling requirements. The cold climate conditions and higher energy costs of North West Territories and Yukon give special meaning to windows having high thermal resistance. In some remote communities the electric heating cost is as high as $0.72/kWh. It is estimated that the high thermal performance glazing unit with "traditional" hardware can result in tremendous energy savings and provide a payback period of less than three years for the incremental costs.

Table 4.8: Energy and Dollar Savings Potential for Windows per Square Metre of Window

Type of Window	Yellowknife		Whitehorse	
	kWh/m²	$/m²	kWh/m²	$/m²
Standard Double	Base	Base	Base	Base
Super Double	255	31.00	215	15.05
Standard Triple	146	17.74	121	08.47
Super Triple	318	38.64	262	18.34

4.1.8 Penetration of High Performance Window Technology

The major barriers to the more widespread use of high thermal performance window are as follows:

- There are concerns about the durability and life expectancy of low-emissivity coatings and argon gas retention because of the high failure rate of these window units in their early stage of development (window units made before 1985). The changing technology and improvements in the production process have increased the durability and life expectancy of these units. However, there is a need to establish their long term performance.

- Lack of performance information: There has been very little monitoring of their effectiveness and few comparisons have been made between different building designs.

- Lack of design knowledge and awareness: Few building designers and architects are aware of, or able to calculate and portray, their cost-effectiveness and comfort performance.

- Current building design practices and codes: Window standards do not include energy performance targets. As well, current HVAC design practices are based on the presumptions that the windows account for maximum solar gains (unwanted heat gains) in the cooling season and lose maximum heat during heating season.

- Lack of understanding and awareness of "systems approach" in the design of commercial buildings: The concept of using window and skylight design and internal layout to increase daylighting contribution in buildings, while at the same time reducing electrical, space heating, or cooling loads, is not widely understood.

- As the technology is still developing, the incremental cost for high performance windows is still considered too high to generate large interest.

With appropriate steps taken to increase knowledge of the new window technologies in the building design profession, there will be growing number of new buildings and renovations with appropriate high performance windows. The following actions will help in achieving significant utilization:

- Modification of building codes and window performance standards to encourage the use of high thermal performance windows. The development of standard test procedures for thermal performance would ensure even-handed competition and increase consumer confidence. Thermal performance labelling would be helpful in the progress of this technology. Energy performance requirements in the window standards will help the energy conserving window products.

- Demonstration and documentation of high performance windows, and design case studies.

- Development of technical and architectural design skills, and easy access to expertise.

- Continued emphasis on research and development of better windows, design strategies, and demonstration of systems.

- Renewed emphasis on energy conservation and its environmental as well as economic benefits.

- Promotion of high thermal performance windows in the regions having high energy costs.

- Emphasis on "whole building system" thinking and design practice: Current HVAC design practices are based on the presumptions that windows account for maximum solar gains (unwanted heat gains) in cooling season and lose maximum heat during heating season, the new windows can allow less costly and more economical approaches to HVAC design in most buildings.

4.1.9 Major Research and Development Priorities

Research, development and marketing needs go hand-in-hand. Certainly, publicly funded research and development programs have accelerated the commercialization of energy conservation technology. A major thrust in the development of low-emissivity coating technology, for example, is attributed to the research and development efforts of U.S. Department of Energy. The window industry and public sectors must push for research and development to help promote full usage.

Accelerated usage of high performance windows will be gained by emphasizing the following research and development activities:

A. Window Product and Process Development
   1. Thermal performance improvement of spacer and frame components with design, material selection and production process
   2. Durability and reliability aspects of high performance windows
   3. Installation and maintenance aspects of high performance windows
   4. Development of innovative fenestration systems

B. Standards and Window Energy Performance Labelling
   1. Development of window thermal performance standards and product evaluation procedures[32] and incorporation in national and provincial building codes.
   2. Development of window energy performance labelling for easy comparison by consumers.
   3. Window specification procedures

C. Demonstration of "proven" window technologies
   1. Demonstration of the use of high thermal performance windows in a "high-profile" commercial building and a residential building. Seasonal or annual performance monitoring and data analysis of selected buildings across Canada would provide credibility to the energy savings potential of high performance windows.

D. Design, Training and Information Transfer Activities
   1. Fenestration System Analysis: high performance window integration with the building envelope, HVAC system design, and cost benefit analysis.
   2. There is a need to assess the impact of high thermal performance windows on utility load demand and the assessment of consumer incentives to achieve the energy conservation benefits.
   3. Potential impact of high thermal performance windows in the retrofit market.
   4. Consumer information, fact sheets of high performance windows, and performance database of windows.

4.1.10 Summary

The energy analysis presented here shows that the currently available high performance windows have a passive solar potential of 0.6 GJ/m^2/year to 0.9 GJ/m^2/year depending on the location. Apart from the energy savings, high performance windows also improve indoor comfort and reduce condensation and related deterioration.

A realistic window market scenario, presented here, shows that the currently available high performance windows have a passive solar potential of 0.37 PJ in 1990. A steady growth rate of 4.5% in the high performance window market would increase the passive solar potential to 10.3 PJ in the year 2010. The total energy contribution of high performance windows by that year could be 83.6 PJ/year.

Preliminary analysis of cost-benefits achieved by the use of high thermal performance windows - even without counting the cost savings achievable in the whole house - show a payback period of 4 to 8 years, depending on window type, when compared with standard double glazed windows in residential houses. These payback calculations for windows do not attempt to include the value of secondary benefits, which can be substantial.

The exploitation of such a large passive solar contribution would require emphasis on window research and development activities directed towards commercialization. The industry, as well as federal and provincial energy ministries, should support such R&D as a highest energy conservation priority.

4.2 Case Study on Daylighting in Non Residential (Commercial) Buildings

The integration of daylight and electric light during daytime hours can provide a comfortable work environment and reduced energy costs. The successful integration depends on building layout, window design, the type of electric lighting control, the HVAC system, local climate, and the utility rate structure. The key requirement in designing the building interior for daylighting is to match space functions with daylighting availability. Daylighting works best where modest fluctuations in light levels are acceptable. Where possible, these areas should be located around the perimeter of the building or in the atrium. In most modern offices, an ambient lighting system is used to establish a general lighting level; task lighting provides additional light at the work station. Reverting to the daylighting approach, offices can be located at the building perimeter with natural light used to provide the ambient lighting. Daylighting features must be incorporated into the building at the design stage, requiring collaboration between the architect and the mechanical and lighting engineers.

4.2.1 Background

The energy savings potential with daylighting in Canada is large. About 14 million m^2 of new commercial floor area is built every year. Of this, the commercial space for offices, retail stores, schools and hospitals, where daylighting can be used effectively, comprises of 9 million m^2. For a typical office design, which is generally a rectangular multistorey building, approximately 28 per cent of the floor space is in the perimeter area[33] and therefore has daylighting potential. This assumes office space with perimeter windows only and does not include daylighting enhancement features such as light shelves, light pipes or atria. However, these daylighting enhancement features would increase the potential for daylighting either by increasing the floor area served or by increasing the luminance in the work space. New construction of approximately 2.5 million m^2/year of building perimeter area could realize savings through the reduced use of artificial lighting, and hence lower electrical lighting consumption, lower cooling loads and reduced peak electrical demand.

4.2.2 Daylighting Strategies

Two daylighting scenarios will be considered. First, that daylight is used for ambient lighting in the office space and provides 300 lux (30 footcandles) for this purpose and, second, that daylighting can be used for task lighting at a level of 500 lux (50 footcandles). A simple on/off control will be assumed for the artificial electric lighting system to supplement the ambient daylighting condition; an automatic dimming lighting control scheme will be assumed for the artificial electric lighting system to supplement the task daylighting. For the results presented here, it is also assumed that interior shading is used to control glare and excessive solar gains[34].

4.2.2.1 CASE 1 - AMBIENT DAYLIGHTING

A recent study at Lawrence Berkeley Laboratory shows that, at a 300 lux (30 footcandle) daylighting level, with an effective aperture of 0.15 and on/off lighting control, a saving of 50 per cent is achieved in lighting energy consumption, as compared to a non-daylit building[35]. For buildings having vertical windows, it has been shown that the use of a single parameter - *the product of the window-to-wall ratio and the solar visible transmittance* - adequately defines daylighting performance, simplifies the analysis and yields accurate results. This lumped parameter is known as *effective aperture.*

In Canada, utility bills for commercial buildings generally range from \$10.00 per m^2 to \$22.00 per m^2 depending on the location. Assuming an average value of \$16.00 per m^2, and that electricity accounts for 90 per cent of the total bill and lighting costs approximately 40 per cent of the electrical bill, then annual lighting costs are \$5.76 per m^2. These assumptions are deduced from the data published by Ontario Hydro in 1988. As shown above, the 50 per cent savings resulting from the use of daylighting as ambient lighting would achieve an annual saving of \$2.88 per m^2 of floor area.

Cooling and heating load changes with the use of lighting controls are also encountered, but these depend upon the installed lighting power and the climate. For a lighting density of 18.3 W/m^2, the annual cooling load would be 50 per cent lower while the heating load would be 30 per cent higher as compared to the non-daylit building, at an effective aperture of 0.15. Heating costs are approximately 12 per cent of the total utility bill while electrically powered cooling accounts for 11 per cent [Data obtained from Ontario Hydro's publications]. This translates to an additional saving of \$0.3 per m^2 (i.e., \$16 x {(0.5 x 0.11) - (0.3 x 0.12)}). The total lighting energy savings of \$3.18 per m^2 would result in net 8 million dollars in *annual* electrical lighting savings for new construction floor space (2.5 million m^2) in Canada.

Lighting control schemes range from a simple scheduling of the lights to more elaborate photo-sensor lighting control[36] . The following table gives their capital costs:

Table 4.9: Lighting Control Costs

	\$/m^2
Scheduling (on/off)	2.08
Photo Sensor (dimming)	15.15

The net life-cycle cost calculations assume that the general inflation rate is equal to the energy inflation rate. The average interest rate for the 10 year period is assumed to be 9 per cent while the inflation rate is assumed to be 4 per cent. The net life-cycle cost (present-value) savings for scheduled control for a period of 10 years are estimated to be \$50.5 per m^2 or \$126 million for one year of new construction in Canada. Of course, each new year of construction could add to this total, so that over ten years the net present value savings in Canada could be \$5,780 million, using ambient daylighting in new construction.

4.2.2.2 CASE 2 - TASK DAYLIGHTING

A 500 lux (50 footcandle) task lighting level with an effective aperture of 0.15 and continuous dimming control can result in a 57% reduction in annual electric lighting consumption. Using the previous estimated value of \$5.76 per m^2 for the annual lighting cost, then the annual electric lighting savings become \$3.28 per m^2. Variations to the heating and cooling loads based on a 18.3 W/m^2 installed lighting density are a 40 per cent increase in heating and a 67% decrease in cooling. This adds an additional saving of \$0.41 per m^2 (i.e., \$16 x {(0.67 x 0.11) - (0.4 x 0.12)}), for a total saving of \$3.69 per m^2. In terms of new construction in Canada, annual savings would amount to 9.2 million dollars.

The capital cost of controls for task daylighting would generally be higher since the desired illuminance must be provided at all times. A photo-sensing dimming control scheme would be recommended. The previous table details the cost for such a control system. The net life-cycle cost (10 years) savings are estimated to be \$58.62 per m^2 or \$147 million for the first year of new construction in Canada. Each new year of construction could add to this total so that over ten years the net present value savings in Canada could be \$6,740 million, using task daylighting.

Assuming a combination of ambient and task daylighting in equal proportions, the integration of daylighting strategies in the new commercial building construction would have life-cycle present-value savings of \$6,260 million over a period of 10 years.

4.2.2.3 CASE 3 - RETROFITS

There is approximately 573 million m^2 of total non residential (commercial) space in Canada. Assuming 10 per cent of this floor area could require lighting improvements and, of these, 25 per cent has daylighting potential, then 14.3 million m^2 of floor space could be used to provide electric lighting and thermal load savings by use of daylight[34]. Retrofit and renovation activities in commercial buildings for increasing the daylighting potential mainly includes ambient daylighting by providing atria, skylights or light shelves. Assuming that daylighting provides only ambient lighting (300 lux) at a saving rate of \$3.18 per m^2 (as previously determined), then there exists an annual energy saving potential of \$45 million over non-daylit retrofit jobs.

4.2.3 Summary of Potential of Daylighting in Commercial Buildings

The integration of daylight and electric lighting can provide a substantial reduction in lighting energy as well as in heating and cooling energy.

<u>**New Construction:**</u>

In ambient lighting, the daylighting energy saving of \$2.88 per m^2 of floor area translates into 0.197 GJ/m^2 per year. In task lighting, the daylighting energy savings of \$3.28 per m^2 is equivalent to 0.22 GJ/m^2 per year.

Assuming an equal combination of ambient and task daylighting design features, in new commercial construction, lighting energy savings of 0.21 GJ/m^2 per year could be realized. This translates to total savings of 0.53 PJ/Year in a 2.5 million m^2 floor area. An average eight percent increase annually in new construction space <u>with</u> daylighting features would increase the potential energy savings from 0.53 PJ in 1990 to 1.14 PJ in the year 2000. Table 4.10 shows the energy savings potential in the new construction.

Retrofit of Existing Commercial Building Stock:

The retrofit of 12.3 million m^2 of commercial space (out of existing 350 million m^2) has the potential of saving 2.42 PJ of lighting energy in Canada.

Table 4.10: Daylighting Potential in New Construction

Year	Potential Energy Savings PJ/Year	Total Energy Savings PJ/Year
1990	0.53	0.53
1995	0.78	3.89
2000	1.14	8.82
2005	2.02	16.96
2010	3.55	31.31

4.2.4 Daylighting with High Thermal Performance Windows

With the availability of high thermal performance windows, having more than two or three times greater thermal resistance values and lower solar transmittance, daylighting in commercial buildings is more attractive than ever before. Low-emissivity coating on glass reduces the solar transmittance of glazing units, which helps in reducing the solar gains.

As shown in Table 4.11, the thermal performance of a double glazed insulating glazing unit is increased from RSI 0.36 to 0.70 by argon gas filling and a low emissivity coating, and the solar transmittance in the visible spectrum reduced from 0.80 to 0.73. Commercial windows generally consist of windows with colour treated glass such as bronze, green or grey tint, to reduce glare and solar gains through windows. When compared with the commonly used bronze tinted glazing unit, the low-e coated glazing unit has a higher visible solar transmittance and of course higher thermal resistance. The low-emissivity coatings reduces the ultra-violet spectrum by 50 per cent and infra-red spectrum by 90 per cent. Higher thermal resistance as well as visible transmittance give a distinct advantage to high performance windows: they provide more daylighting while substantially reducing heat gains and losses.

Simple calculations show that, for an ambient daylighting level of 300 lux with an aperture of 0.19, and on/off control, a saving of 58 per cent in lighting energy consumption is realized, as compared to a non-daylit building. This translates to total lighting energy savings of $3.74 per m^2 of office space in Canada. The total lighting energy savings would result in net 9.3 million dollars in *annual* electrical lighting savings for new floor space in the country.

Similar calculations can be made for the task daylighting strategy. There is a need to analyze, in detail, the effects of high performance glazing units on space heating and cooling, HVAC design and equipment sizing, and daylighting.

Table 4.11: Thermal Performance Data for Various Commercial Glazing Assembles. Outer glazing is 6 mm and inner glazing is 3 mm thick, and air-space is 12.7 mm.

Type of Glazing Unit	RSI-Value	Solar Transmittance	
		Solar	Visible
Single Glazed (3 mm)	0.16	0.84	0.90
Single Glazed (6 mm)	0.16	0.77	0.88
Double, clear 12.7 mm air space	0.36	0.65	0.80
Double, Bronze	0.36	0.41	0.48
Double, Green	0.36	0.41	0.48
Double, Grey	0.57	0.38	0.39
Double, Low-E coating, air filled	0.70	0.53	0.73
Triple, Low-E coated thin plastic glazing (Heat Mirror 88) (8 mm air space)	0.62	0.44	0.70

4.2.5 Discussion

Daylighting is an effective means for reducing the amount of electrical energy required to provide suitable light levels. Availability of daylight is of course the primary factor, while building design is also a crucial factor. This includes the location and size of windows and skylights, the shape of the building, and the corresponding ratio of interior to perimeter floor areas. It also includes the position, shape, and colour of interior partitions, ceilings, floors, and furnishings.

The window type can have a significant impact on the effectiveness of daylighting. Windows need not be oversized for effective daylighting; it is more important to select windows with the right thermal and optical properties. For daylighting applications, windows should have a high visible light transmittance and a low solar heat gain transmittance; ultraviolet as well as infrared radiation should be blocked without appreciable loss of visible light.

Natural light can contribute to interior lighting requirements up to a depth of 2 to 2.5 times the height of the windows when measured from the floor to the top of the windows. Thus, a window located high on a wall will be more effective than a low-mounted window. For a typical office, daylight from perimeter windows can illuminate a zone five to six meters in depth. In lighting design, selection and layout of the lighting control system is important. Various devices are used to control the use of energy for artificial lighting when daylight is available. These can be categorized as switching and dimming systems. These rely on photocell devices to sense the amount of daylight available. Retrofits to buildings which increase daylighting are limited. One of the retrofit strategies is the installation of skylights and light shelves.

Daylighting as an energy conservation strategy in building design requires detailed energy analysis, with a complete systems approach, to determine its cost-effectiveness. The increase in daylighting is proportional to the glazing area. With the advent of high thermal performance glazing units, with more than two or three times greater insulation values and lower solar transmittance (resulting in lower solar gains), the daylighting strategy is more attractive than ever before since much more glass can be used, completely economically.

4.2.6 Field Experience

Many recently constructed buildings incorporate architectural features which make effective use of daylight. In some new office buildings, dimming controls are integrated into central automated control systems.

One such example is the Southland office building in Calgary. Integration of natural sunlight with the lighting control system during the design stage has allowed effective use of daylighting[37]. The computer analysis for this 30,000 square metre building showed that the lighting control system and the use of daylighting has the potential of reducing both the lighting and cooling energy consumption by 40%: an annual savings of over $250,000. The peak cooling requirement was reduced by over 25%. The savings in equipment size reductions - less chiller capacity - was estimated to be additional $75,000. The complete daylighting and lighting control system provides flexibility in lighting levels and has been welcomed by the users.

4.2.7 Solar Light Pipe Technology

A Canadian company, TIR Systems Ltd. of Vancouver, conceived and developed an innovative solar light pipe system. A light pipe relies on the principle of total internal reflection. The pipe is a hollow rectangular tube lined with sheet plastic, with a prismatically shaped surface finish to transmit light along its length.

Solar light pipe technology has been successfully demonstrated in more than two commercial installations in Canada. A 220 square metre canteen facility was monitored for a period of one year to establish the lighting energy savings using light pipes. It is estimated that the solar light pipe system was able to reduce the electric light consumption by 10,000 kWh/year. The total installed cost (material + labour) of the light pipe system was more than $25,000. The simple payback period is more than 30 years for such a system.

The light pipe technology is still under development. Cost-effectiveness and optimization of the system components are yet to be achieved. The commercial success of this innovative technology will depend on its cost-effectiveness. By the year 2010, light-pipe technology will probably make only a minimal contribution to meeting lighting energy requirements.

4.2.8 Penetration of Daylighting Technology

The major barriers to the more widespread use of daylighting are as follows:

- A general lack of performance information on daylighting. There has been very little monitoring of the effectiveness of daylighting systems and few comparisons made between different building designs.

- Current building design practices and codes. These were designed to minimize the use of daylight as a light source (to reduce the solar gains) and the use of windows as a means of ventilation. Current HVAC design practises are based on the presumptions that windows account for maximum solar gains (unwanted heat gains) in cooling season and lose maximum heat during heating season.

- Lack of design knowledge, understanding and awareness. The concept of using window and skylight design and internal layout to increase daylighting contribution to building, and consequently, reduction in electrical and space heating or cooling loads, is not widely understood.

- It is difficult to increase daylighting in existing buildings except during major renovations.

With appropriate steps taken to increase the knowledge of daylighting and to educate building designers, there could be growing number of new buildings and renovations with effective daylighting strategies. The following actions will help in achieving significant utilization of daylighting:

- Modification of building codes to encourage or regulate the use of daylighting. As an example, in California the building code has prescriptive instructions regarding daylighting. In Paris, all office building work-stations must be no more than 5 metres from the window[38].

- Demonstration and documentation of daylighting system performance, and design case studies.

- Development of technical and architectural design skills for daylighting, and easy availability of "daylighting expertise".

- Widespread dissemination of daylighting information to building owners and designers; development of training courses in daylighting for building designers, lighting designers, and HVAC engineers.

- Continued emphasis on development of better windows, daylighting strategies, and lighting control systems.

The integration of daylight and electric light can provide a comfortable work environment with substantially reduced energy costs.

4.3 Case Study on Thermal Storage and Integrated Mechanical Systems

In the context of passive solar contribution, the thermal storage strategies help in improving the utilization or management of heat gains. Both solar and internal gains are stored and released depending on the building heating needs. Thermal storage strategies also help in storing excess heat during peak cooling hours and releasing it in off-peak hours, thereby reducing the air-conditioning loads during peak hours.

Efforts to control temperature swings and improve passive solar utilization have employed high-mass elements such as concrete floors, brick feature walls and double drywall. Other strategies include Trombe walls, water walls, and rock storage. Although adequate control of temperature swing has been demonstrated, the payback in terms of energy savings has never been attractive. Recent research and development has led to solutions that may more readily and economically be incorporated into standard building practice. Hence, this case study focuses on those products or processes.

4.3.1 Phase-Change Material (PCM) Wallboards

Phase-change materials have been investigated by a number of researchers. Encapsulation and impregnation into gypsum board has been attempted with success although commercialization has not yet been realized.

In Canada, Energy, Mines and Resources has funded research and development projects related to phase-change material dry wallboard. One such project at Concordia University has been successful in developing the unique process of impregnating a phase-change material in standard gypsum dry wallboards. As shown by the researchers[39], an average Canadian home has 300 m^2 gypsum wallboard; if a half-inch layer of PCM wallboards was used, it would provide thermal storage of 105 MJ with a 7 degree C room temperature swing. The storage and release of heat gains could enable energy savings of 5.1 GJ (1,420 kWh or $70.00 in 1989 costs) every year. The "first trial" production run of PCM wallboard showed an incremental cost of $4.00/m^2 of wallboard which could result in a simple payback period of 18 years.

However, as the manufacturing process is optimized with mass production the incremental cost of producing PCM wallboard should reduce considerably, to less than $1.50/m^2. The PCM thermal storage will not only save energy but will also reduce the peak demand. These considerations should lower the payback period of PCM wallboards for larger usage in new housing. The PCM wallboard thermal storage has considerable potential for energy savings and peak demand reduction in cooling-dominated usage[40], and therefore should be of interest to electric utilities in densely populated urban divisions.

It is assumed that the PCM wallboard technology is in an advanced stage of development and the first field applications will be in 1992. Thereafter, up to 1997, the PCM-gypsum wallboard technology will be "market perfected" and rate of use will increase at a faster pace. It is assumed further that by 2010 fifteen percent of new housing will use the PCM-gypsum wallboards. The following Table 4.12 shows the passive solar contribution potential of PCM wallboards.

Table 4.12: Passive Solar Contribution of PCM-Gypsum Wallboard Thermal Storage.

Year	Housing Completions (Units/Year)	PCM Wallboard Usage in New Constr. (Units/Year)	Potential Energy Savings (PJ/Year)	Total Energy Savings (PJ/Year)
1990	161000	0	0.000	0.000
1995	174000	1700	0.009	0.028
2000	188000	4300	0.022	0.107
2005	203000	1200	0.066	0.336
2010	219000	33000	0.182	0.966
Total	Units	Units		PJ
1990-2010	4129000	177000		4.86

A 15 percent market penetration of PCM wallboards by the year 2010 in the new residential building stock would reduce the energy consumption by 0.97 PJ/year. PCM-gypsum wallboard technology may be developed to its full potential by the year 1992.

4.3.2 Integrated Mechanical Systems

The Integrated Mechanical System concept, IMS, links the various energy requirements and flows in a building to use less energy and less capital. The linkage include space heating, cooling, hot water and ventilation energies, with utilization of passive solar and lighting energy; refrigeration, and waste energy flows from washing, and drying of laundry and dishes, may also be linked.

IMS converts passive solar and internal heat gains into useful space heating contributions by distributing these gains throughout the building, where and when required. Heat need not be rejected. Residential Integrated Mechanical Systems consist of a combination of space heating, hot water heating, an air-to-air heat exchanger, a ventilation system, and thermal storage. Also, heat pumps can be used to convert solar and internal heat gains to useful space heat or domestic hot water as well as recover heat from exhaust air or grey water. Hybrid systems employing heat pumps to cool the space and store heat have been investigated. The demonstrations and simulation studies indicate the technical feasibility and reliability of integrated mechanical systems. However, the cost/benefit position of these systems depends on the application, available energy sources, and cooling requirements. Thermal storage media include water, ice/water phase change, and earth storage. Storage schemes range from overnight storage to seasonal. Interest in electrical peak load reduction by night-time storage has grown rapidly and may interface well with passive hybrid solar technologies[41]. Integrated Mechanical System technology can be easily applied to new housing where the required air handling duct work and flow lines can be installed without any additional costs. The retrofit application of IMS may be limited due to potential high-cost modification to existing heating, cooling and heat recovery systems, but heat pump heat recovery from the ventilation exhaust may offer economical retrofits.

To date, residential building designers have tended to avoid large solar gains due to concerns about discomfort. In combination with high thermal performance windows, further energy savings have been predicted. An initial feasibility and demonstration study shows a reduction in the energy consumption of 8 to 10 per cent[42]. The annual energy savings for a highly insulated house can be 8 to 10 GJ, while a moderately insulated house can save 10 to 12 GJ, with the use of an integrated mechanical system; these savings are largely additional to those given before for passive solar features without IMS.

A number of different types of IMS are now available on the market. These units are performing reliably. Market size and take-up of these systems are difficult to estimate, and hence predictions are based on stated scenarios of market penetration. The utilization of IMS in the new residential housing stock to say, 3.5 per cent in 1990, increasing to 66 per cent by the year 2010, would provide a 9.74 PJ/year contribution to the housing energy needs as shown in Table 4.13. From the above calculations it can be seen that the integrated mechanical systems have a good energy savings potential. As well IMS, can help in maintaining the indoor environment with continuous ventilation. Further study is recommended to explore the full potential of IMS. The introduction of the high thermal performance windows clearly invites the use of integrated mechanical systems to provide these largely additional energy savings.

Table 4.13: Energy Savings Potential of Integrated Mechanical Systems

Year	Total Housing Completions (Units/Year)	Market of IMS Units		Energy Savings (PJ/Year)	Energy Savings (PJ/Year)
		% New Housing	Units		
1990	161000	3.5	5600	0.05	0.09
1995	174000	7.1	12400	0.11	0.48
2000	188000	16.3	30600	0.26	1.41
2005	203000	32.8	66500	0.70	4.04
2010	219000	65.9	144500	1.52	9.74
Total	Units		Units		PJ
1990-2010	4129000		954118		56.10

4.3.3 Innovative Passive Solar Concepts Applied to Buildings

Passive solar is, basically, a design philosophy consisting of collection and efficient utilization of solar gains. There are several innovative and reliable design concepts, such as rock-bed seasonal or diurnal storage, and

Trombe-wall, that have been used with some success. However, these concepts did not make inroads into building markets due to their cumbersome nature and low efficiency.

Other design approaches are emerging or being explored. The following emerging concepts may hold promise: (1) ventilation windows, (2) dynamic solar walls, (3) displacement ventilation, and (4) transparent insulation. In this report, the assessment of passive solar potential does not include such passive solar design concepts due to lack of performance data. A survey of these emerging technologies show that these will be present in the market place as a "unique demonstration" rather than wide acceptance, at least to the year 1995. The procedure developed in this report can be applied to assess their potential.

4.4 Summary of Technical and Economic Assessment

Energy analyses show that the currently available high thermal performance windows have a passive solar potential of 0.6 to 0.9 GJ/m^2/year. Cost-benefit analyses predict a payback period of 4 to 8 years depending on window type, location and heating fuel. A steady growth rate in the high thermal performance window market, at 4.5% to the year 2000 and 3.5% thereafter, would enable total passive solar contribution of 84 PJ/year in the year 2010 in all buildings.

The use of daylighting in commercial buildings holds a promising future for increasing the passive solar contribution. The retrofit of existing commercial buildings for incorporating daylighting has a limited potential of 3 PJ/year in the year 2010. The use of daylighting in new commercial buildings would contribute 31 PJ/year in the year 2010.

The integration of house mechanical systems with heat recovery has an additional potential of supplying 8 to 10 GJ/house/year as passive solar contribution, resulting in simple payback period of less than 3 years. It is projected that 23% of new residential buildings will use integrated mechanical systems by the year 2010, resulting in supply of passive solar energy of 10 PJ/year in the year 2010.

The phase-change wallboard technology holds promise for contributing 1 PJ/year in the year 2010 in the new residential buildings. Innovative thermal storage strategies would contribute 2 PJ/year in new commercial buildings in the year 2010.

The technical and economic assessment analysis shows a reasonably achievable potential of 131 PJ/year in the year 2010. The utilization of clearly emerging passive solar technologies would be less than 30% of building stock by the year 2010.

5. MARKET PENETRATION SCENARIOS

Passive solar contributes 48 PJ/yr in the existing buildings in the year 1988. This contribution represented about 4.4% of the total building space heating energy needs, or about 0.75% of the gross national energy requirements. As indicated earlier in the assessment section, 363 PJ/yr by the year 2010 has been identified as a technically feasible energy conservation potential for current and clearly emerging passive solar technologies. The incentive to promote the acceptance of these technologies is indeed very high.

As shown earlier in Section 4, high thermal performance windows, daylighting, integrated mechanical systems and thermal storage technologies are almost fully developed and clearly emerging as the main passive solar technologies. Section 4 also presented analyses of various uptake rates of acceptance of these technologies in the existing and new building stock by the year 2010. A market scenario is presented here to show the reasonably achievable market potential for passive solar utilization in buildings.

5.1 Existing Residential Stock: Retrofit Potential

The single technology that clearly can be applied to existing dwellings to improve energy performance is high thermal performance window technology. A technically feasible potential of 136 PJ/yr is possible in the year 2010 by replacing existing windows with high thermal performance windows (RSI 1). A case study on these windows showed that, with an annual uptake rate of 4.5% in window replacement in existing buildings to the year 2000 and 3.5% increase thereafter, the passive solar contribution would be 36 PJ/yr in the year 2010. The above rates of uptake in existing residential buildings, which are rather normal replacement rates, would replace windows in 3.1 million units, representing 32% of existing residential building stock by the year 2010.

5.2 New Residential Construction (from 1989-2010)

The promising passive solar technologies identified with new residential construction are: (1) high thermal performance windows, (2) thermal storage, and (3) integrated mechanical systems. Virtually all new houses and apartment buildings can currently be built with these new technologies to make them more efficient users of solar energy. The "reasonably achievable" market penetration scenario is as following.

As shown in Section 4.1, with a projected 7% high performance market in 1990, increasing to a 34% in the year 2000, and a 67% market in the year 2010, windows in new residential buildings will contribute 14 PJ/yr in the year 2010. It is projected that 1.3 million new residential buildings will then use these remarkable windows, comprising 32% of that stock.

The use of integrated mechanical system in new residential buildings, at a rate of 3.5% in 1990, increasing to 16% in the year 2000, and a 66% in the year 2010, will contribute 10 PJ/yr in the year 2010, as projected in Section 4.3.2. A 23% of new residential buildings will use these integrated mechanical system by that time.

The use of thermal storage options, such as phase-change material wallboards, in new residential buildings will contribute 1 PJ/yr in the year 2010. The PCM wallboard technology is still under development and is expected to be commercially available by the year 1994. As projected in Section 4.3.1, about four percent of new residential building stock by the year 2010, will use this technology.

In sum, new residential construction holds a "reasonably achievable" promise of a passive solar contribution of 25 PJ/yr in the year 2010. That can be gained by using the emerging passive solar technologies in less than 30% of new residential construction. This seems a reasonably likely forecast.

5.3 Retrofit Potential in Existing Commercial Buildings

The main passive solar technologies that can be retrofitted to existing commercial buildings are high thermal performance window and daylighting. A technically feasible potential using today's best available window technology is about 100 PJ/yr in the year 2010. In a reasonably achievable market penetration, where replacement of windows will occur in less than 20% of existing commercial buildings and retrofit for daylighting will be done in 2.5% of buildings, the energy contribution will be 23 and 2 PJ/year respectively, for a total of 26 PJ per year in 2010.

5.4 New Commercial Buildings (from 1989-2010)

The promising passive solar technologies identified with the new commercial construction are: (1) high thermal performance windows, (2) daylighting, and (3) thermal storage. Virtually all new commercial buildings could currently be built with these new technologies to make them more efficient users of solar energy. Integrated mechanical systems are already featured in much of new commercial construction to good effect.

It is projected that high performance windows (RSI 1) will be used in 22% of the new commercial buildings contributing 11 PJ/yr in the year 2010.

The major contribution to passive solar, in new commercial buildings, will be gained from the use of daylighting. As projected in Section 4.2, about 35% of the new commercial construction will utilize daylighting. The passive solar contribution will be 31 PJ/yr in the year 2010 in this scenario.

Thermal storage technologies for commercial buildings are well developed and in use. The use of innovative thermal storage options, such as PCM wallboard, will contribute 2 PJ/yr in the year 2010 in this scenario.

In sum, new commercial construction holds reasonably achievable promise of a passive solar contribution of 44 PJ/yr in the year 2010. That can be gained by using the emerging windows, daylighting, and thermal storage technologies in less than 35% of new commercial construction.

5.5 Market Issues Relating to Canadian Housing

General Impediments to Substantial Market Penetration of Solar Technologies

The impediments to, and means of encouraging, traditional Passive Solar Technologies (such as, rock-bed storage, Trombe-wall...) have been well covered in the earlier studies for Passive Solar. Impediments to the penetration of new passive solar technologies in the Canadian residential and commercial markets are structural, attitudinal, financial and technical. The following is a brief evaluation of perhaps the strongest impediments that would have to be addressed before substantial market penetrations are achieved with the various passive solar technologies discussed in this report.

Structural Impediments

Passive solar designs necessarily involve components of the building envelope. Most components are very durable with lives ranging anywhere between 10 and 100 years or more. The main impediment to improved passive solar energy for existing structures is the "durability" of the existing structure. "Durability" refers to the technical longevity of various portions of the envelope as well as the building owner's perception of the functionality or technical integrity of these envelope components. The evaluation of the performance of many components is therefore rather subjective. For example, a cracked window pane in an innocuous place may be just as thermally functional as a new one. The replacement of that pane will be a function of many factors that move the owner to make the expenditures to replace or upgrade components.

The durability of low-emissivity coating on glass or the inert gas filling of windows needs to be assessed using accelerated performance tests. However to a large extent, structural impediments cannot be removed; they have their own time frame. Nevertheless, policy could be formulated to target those structures whose useful life spans have been reached.

Attitudinal Impediments

The homeowner's perception of the need to change or upgrade a building component is related to the financial evaluation of the passive solar technology. At the point of decision for upgrade or at the point of decision for material selection of building construction, builders and building owners are faced with a multitude of selections and priorities, all of which have to be taken into account for a final building design. As well, community subdivision layout and planning all have an important role to play and all these can involve attitudinal impediments to a passive solar market penetration.

There are many demands made on building owners' budgets that may take precedence over energy conservation. Because of the great benefits of passive solar technologies in terms of their ability to extend the utility of envelope components at little extra cost, it is important for authorities to disseminate the benefits of integrating passive solar designs into the building system at the point of design or the point of retrofit or renovation. A strategy must be developed that raises the passive solar considerations from the level of "yet another consideration" to the level of primary consideration in the design and selection of materials. If the national interest for energy conservation is high enough, passive solar considerations (e.g. a target Energy Performance Index of the solar aperture) could be included in the national building code in the same way that specifications for insulation levels have been integrated into the code.

It is not the intention of this study to get into the pros and cons of prescriptive measures as opposed to performance targets; the above example of inclusion of passive solar standards into the building codes is merely an indication of how to get passive solar features of construction into the right arena of planning at the right time.

The best means of combatting attitudinal impediments is to develop marketing strategies. These strategies are perhaps best approached by marketing firms who specialize in marketing quality products that may have a cost premium as well as easily identifiable advantages. To a large extent, EMR's R-2000 Program is an excellent case study in this type of marketing strategy. The R-2000 Program succeeded in becoming recognized to the point where the energy efficient technologies became part of the homebuyer's and home builder's consciousness at the planning stage.

The promoters of passive solar technologies might have a slightly more difficult task in developing a similar marketing strategy in that the R-2000 Program was a performance target program; no one material or approach was favoured over the next. As such it set up a competition among manufacturers and material suppliers and builders while not favouring one over the other. Passive solar technologies, on the other hand, may be in direct competition with other accepted components in the building industry and any extended marketing program of passive solar technologies might be seen by manufacturers and builders as interference with the market process. An appropriate strategy would have to be well thought out before presentation for public consumption.

Financial Impediments

As indicated above, there are a large number of factors that fall under consideration of building owners and builders at the time of construction activity and all of these factors have a cost. The potential additional costs of passive solar technologies are subject to the same cost selection criteria as many other options such as decoration, finishing and so on.

In essence, passive solar technologies are in cost competition with many other options that have little or nothing to do with energy efficiency. As a result, it is imperative that passive solar technologies be properly costed out in advance of the design stage so that the cost and benefits can be easily evaluated by builders and owners who are considering having the work undertaken. Technology transfer and easy means of assessing making cost benefit analyses have to be disseminated, as has been done in the past.

Technological Impediments

As has been seen in recent years, developments in passive solar technologies have occurred quickly and breakthroughs are occurring in the fields of high performance windows, integration of building mechanical systems, phase change thermal storage materials, and daylighting.

Key issues are the durability of the product and the ability of the product to be integrated universally in almost all construction techniques. Here the high performance windows should rank highly. Aside from initial development problems with the technology, the state of the current technology is such that longer term warranties are being offered and backed-up by actual performances of these technologies in the field. The universal applicability of high performance windows in all directions of buildings and the universal appeal of improved comfort in both summer and winter conditions means that this particular technology should catch on very quickly once its success has become widespread knowledge amongst industry and consumers. An enhanced program for durability testing of high performance windows could be undertaken to assist the industry in improving their product and, at the same time, helping the buying public in making an informed decision.

A number of actions are recommended which to a large extent are an extension of previous plans of action in the development of passive solar technologies. These involve further research and development, information and technology transfer about the promising products, assisting industry, and develop testing that establishes reliability and longevity of the product. Measures should be taken to ensure that, at the design and selection stage, the passive solar technologies that have clear benefits for society are brought to light and encouraged.

5.6 Summary of Reasonably Achievable Potential in Building

The assessment and market survey of clearly emerging passive solar technologies projects a passive solar potential of 131 PJ/yr in the year 2010, additional to the passive solar effects in normal play. Table 5.1 shows the reasonably achievable passive solar contribution to the building energy needs. Table 5.2 shows the yearly projections of passive solar contributions.

Table 5.1 Estimate of Reasonably Achievable Passive Solar Potential in the Year 2010.

Emerging Technology	Residential (PJ/yr)		Commercial (PJ/yr)		Total (PJ/yr)
	Existing	New	Existing	New	
High Performance Windows	36	14	23	11	84
Daylighting	-	-	3	31	34
Integrated Mechanical Systems	-	10	-	-	10
Thermal Storage	-	1	-	2	3
Total	36	25	26	44	131

Table 5.2: Estimate of Passive Solar Potential.

Year	Residential (PJ/yr)		Commercial (PJ/yr)		Total (PJ/yr)
	Existing	New	Existing	New	
1995	3.6	2.5	2.6	5.4	14.1
2000	14.4	10.3	10.4	14.2	49.3
2005	25.2	17.8	18.2	26.2	87.4
2010	36.0	25.0	26.0	44.0	131

6. SUMMARY AND CONCLUSIONS

The main purpose of this project is to provide data on the energy conservation potential which can be achieved through the use of passive solar design features and components in the residential and commercial buildings. The main objective is to identify technical feasibility of passive solar potential in existing buildings and in new construction, and also to identify opportunities with respect to research, development and technology transfer activities.

The existing residential building stock consists of 9.69 million residential units comprising 1,021 million m^2 floor area in the year 1988. It is projected that this stock will increase to 13.8 million units (1,494 million m^2 floor area) by the year 2010.

The existing commercial building stock consists of 0.59 million units comprising 573 million m^2 floor area in the year 1988. It is projected that this stock will increase to 0.89 million units (858 million m^2 floor area) by the year 2010.

The passive solar potential in residential and commercial buildings is assessed using the definition of passive solar as a net solar contribution to meeting the building energy requirements additional to that already in play in buildings. The assessment of passive solar yields three levels of estimates of conservation potential:

- **ultimate potential** - a conservation potential that would be realized if all technologies were developed to the fullest and applied universally;
- **technically feasible potential** - a conservation potential that could be achieved if all currently available and clearly emerging technologies were applied universally; and
- **reasonably achievable market potential** - developed by postulating scenarios of market penetration of these available and clearly emerging technologies.

The present passive solar contribution to the building energy in the existing residential and commercial building stock is about 48 PJ/year in the year 1988: 4.4% of total space heating energy, or 0.75% of gross national energy requirements.

Four emerging passive solar technologies have been identified and evaluated for their **additional** potential to conserve energy in Canada's existing residential and commercial buildings, and than in new construction to the year 2010. These technologies are: high thermal performance windows, daylighting, integrated mechanical systems, and thermal storage using phase-change material wallboard. The technical and economical assessment of their passive solar potential in the year 2010 is summarized in Table 6.1. A 363 PJ/year is technically achievable using existing technologies if applied to the existing and new buildings to the year 2010. A reasonably achievable market potential is 131 PJ/year in the year 2010.

Exploitation of such a large passive solar potential would require emphasis on research and product development activities directed towards commercialization and marketing. The clearly emerging passive solar technologies, such as high thermal performance windows, daylighting and integrated mechanical systems, should be prioritized for further research, development and demonstration. Clearly, the new high performance windows alone constitute a "breakthrough" that offers more potential for solar utilization and energy conservation than any other single change in buildings. The industry, as well as federal and provincial energy ministries, should support such R&D as a highest energy conservation priority. Energy supply and economics, and the matter of the environment, are the incentives for such R&D.

Table 6.1: Summary of Passive Solar Potential in Buildings in the Year 2010.

	Ultimate Passive Solar Potential (PJ/Year)	Technically Feasible Potential (PJ/Year)	Reasonably Achievable Market Potential (PJ/Year)
1. Existing Residential Retrofit Potential (to 1988)	296	136	36
2. New Residential (1989-2010)	151	53	25
3. Existing Commercial Retrofit Potential (to 1988)	172	100	26
4. New Commercial (1989-2010)	108	74	44
TOTAL	727	363	131

REFERENCES

1. *Federal Energy Research and Development Program*, Briefing Book for the Long Range Planning, Panel on Energy Research and Development, Energy, Mines and resources Canada, (1987).

2. *Alternate Energy Technology in Canada*, NRC's Energy R&D Program 1975-1985, (September 1986).

3. Barakat S.A., "NRCC Passive Solar Test Facility: Passive Solar Studies at the Division of Building Research", Building Research Note: 188, Division of Building Research, NRCC, Ottawa, (May 1988).

4. Barakat S.A., "NRCC Passive Solar Test Facility: Performance of Direct Gain Units", Building Research Note: 215, Division of Building Research, Ottawa, (May 1984).

5. Barakat S.A. and Sander D.M., "A Simple Method for Determining the Heating Energy Requirements of Direct Gain Through Windows for Heating Houses", Building Research Note: 195, Division of Building Research, NRCC, Ottawa, (June 1982).

6. Mayo T., *Residential Passive Solar Design: A Guide to the Technology*, National Research Council Canada, NRCC No. 26252, (July 1986).

7. Besant R.W., Dumont R.S., and Schoenau G., "The Saskatchewan Conservation House Some Preliminary Performance Results", Proceedings of the Solar Energy Society of Canada, London, Ontario, (1978).

8. Dumont R.S., Besant R.W., Jones G., and Kyle R., "Passive Solar Heating - Results from Two Saskatchewan Residences", Proceedings of the Solar Energy Society of Canada, London, Ontario, (1978).

9. Ten Practical Passive Solar Houses in Eastern Canada, Scanada Consultants Limited, National Research Council Canada, Report No. Passive - 2, (November 1980).

10. Level B Performance Summaries, Solar Energy Development Program, Energy, Mines and Resources Canada, (1986).

11. Renewable Energy Project Digest, *Passive Solar*, Energy, Mines and Resources Canada, Ottawa, (October 1988).

12. Shapiro M.M., Feldman D., Hawes D., and Banu D., "P.C.M. Thermal Storage in Wallboard", 12th Passive Solar Conference Proceedings, Portland, Oregon, (July 1987).

13. *Implementing Passive Solar Energy Technology in Canada*, Report E177-8, Energy, Mines and Resources Canada, (1978).

14. *Development of R&D Plans for Passive Space Heating*, Con-Serve Group and Scanada Consultants Ltd., Prepared for the Solar Energy Program, National Research Council, Ottawa, (1982).

15. Scanada, 1979: Scanada Consultants Limited, *Heating Canadian House: Current Performance and Potential for Improvements*, Prepared for the Canada Mortgage and Housing Corporation, Ottawa.

16. 2020 VISION: 1988-2020, Working Paper Prepared by the Energy and Fiscal Analysis Division, Energy, Mines and Resources Canada, Ottawa, Winter 1990.

17. Statistics Canada, *Fixed Capital Flows and Stocks*, Catalogue 13-211, 1987.

18. Statistics Canada, *Construction in Canada*, Catalogue 64-201, 1971 to 1989.

19. Statistics Canada: *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue 57-003.

20. Parekh A. and Mayo T., "Thermal Analysis and Energy Savings with High-Performance Window", Excellence in Housing '89, Seventh Annual International Energy Efficient Building Conference, Winnipeg, (Mar 1989).

21. *HOT-2000: Version 5.05f release 2.1*, Energy, Mines and Resources Canada, (November 1988).

22. *Utility Rate Survey*, Final Report, Sheltair Scientific Ltd./SAR Engineering Ltd., Energy, Mines and Resources Canada, (March 1989).

23. Personal Communique: with a major window manufacturer, (Mar 1989).

24. Personal Communique: with Ontario Hydro (Jun 1989).

25. Michael Glover, "Potential of Super Window Technology in Canada", Brief to the Energy Options Task Force, (January 1988).

26. *Advanced Passive Solar Technology: The Window Market in The United States and Canada*, Energy, Mines and Resources Canada, (August 1986).

27. Nachmi Artzy, "The Alumi-News Industry Survey", Alumi-News, Vol. 13, No. 2, Jan-Feb 1989.

28. "Best Moving Products - A Dealer's Perspective" and "High Performance Windows Coming of Age", Alumi-News, Vol. 12, No. 4, (June 1988).

29. *The Outlook for 1989 and 1990 Residential Demand for Windows and Patio Doors*, Prepared for Members of National Wood Window and Door Association, National Information Services, McGraw Hill, (February 1989).

30. "Solariums and Glazing", Alumi-News, Vol. 13, No. 3, (May 1989).

31. *Advances in High-Performance Window: The Successful Development of Low-Emissivity Coatings for Windows*, The Role of Federal Research and Development in Advancing Energy Efficiency, American Council for an Energy-Efficient Economy, Washington, (September 1987).

32. *Window Research Priorities Meeting: June 25 1988*, Summary Report, Enermodal Engineering Limited, Energy, Mines and Resources Canada, (June 1988).

33. Johnson, R., Sullivan, R., Selkowitz, S., Nozaki, S., Conner, C., Arasteh, D., "*Glazing Energy Performance and Design Optimization with Daylighting*", Energy & Building, Vol.6, pp. 305-317, (1984).

34. Johnson C.A. and R.W. Besant "*The Potential for Passive Gains and Daylighting in Large Buildings*", Final Report, Energy, Mines and Resources Canada, (1988).

35. Arasteh D., Selkowitz S.E., Johnson R.L., and Sullivan R., "*Energy Performance and Savings potential with Skylights*", ASHRAE Transactions Vol. 91, Part 1A, Paper # 2866, pp. 154-179, (1985).

36. Verderber, R.R., Rubinstein, F.M., "*Mutual Impacts of Lighting Controls and Daylighting Applications*", Energy and Buildings, Vol. 6, (1984).

37. Enermodal Engineering Limited, "*Passive Solar Potential in commercial Buildings: Four Case Studies*", Final Report, Prepared for the Energy, Mines and Resources Canada, (1989).

38. King M.J. and Heidell J.A., "*Testing the Economic Effectiveness of Proposed Revisions to ASHRAE Standard 90*", ASHRAE Transactions 1985, Paper Number: CH-85-12 No. 1, Vol. 91, Part 1, (1985).

39. Shapiro M.M., Feldman D., Hawes D. and Banu D., "PCM Thermal Storage in Wallboard", 12th Passive Solar Conference Proceedings, pp. 48-58, Portland, Oregon, (July 1987).

40. Paris J. and Houle J.F., *Development de Plaques de Platre Avec Emmagasinage Thermique par Changement de Phase*, Final Report, Energy, Mines and Resources Canada, (March 1989).

41. Morofsky E., Parekh A. and Platts R., "*Integrated Mechanical Systems: Recent Developments and Potential Housing Applications*", A state-of-the-art survey prepared by Canada for the First Experts' Meeting of the International Energy Agency Solar Heating and Cooling Implementing Agreement, Task XIII - Advanced Solar Low-Energy Buildings, Boulder, Colorado, November 1989.

42. Allen G. and Kani M., "Integrated Thermal Storage in Energy Systems for Canadian Low Energy Houses", ENERSTOCK '85, Thermal Storage Conference, Toronto, (Sept 1985).

APPENDIX A: PROCEDURE FOR THE ESTIMATION OF CONSERVATION POTENTIAL

A.1 Assumptions Made in the Development of the Estimate of Passive Solar Conservation Potential for the Residential Stock in Canada

The following assumptions and references were made in the development of our estimate of passive solar potential for the residential stock in Canada:

- Double glazing was assumed to have virtually 100% penetration in the housing stock in Canada. In fact, there is likely a remaining small fraction of single glazing in the Canadian housing stock - likely less than 5%. This small quantity has not been accounted for in the window R-value assumption.

- The leakage characteristic of windows was developed using window standard CSA A440 as a reference. The top end of the range of window leakiness specified for storm windows in the standard was assumed to be the average window leakiness across Canada. The sash length to window area ratio was estimated based on typical window examples. The exponential relationship relating air flow to Pascals, was used to translate the characteristic into a "mean air leakage per unit area" that applies over the season. The resulting window loss was noted to be a reasonable percent of the total building loss.

- The average solar transmittance of windows was assumed to be 0.8 for a standard double glazed window, and 0.61 for a high performance window with thermal resistance of RSI 1.0.

- The orientation effect of building stock was included in the assessment calculations. An orientation factor of 1.1 was chosen, based on a limited survey of case studies, for existing building stock. For new building stock orientation factor was assumed to be 1.15. (The orientation factor for randomly oriented windows equals 1, the maximum orientation factor would be about 1.6 if all windows faced south; i.e. south facing windows collect 60% more solar than windows arranged in a random orientation).

- A solar utilization of 0.8 was assumed to account for mass storage (infinite storage capability would have a utilization of 1 if the seasonal heat loss is greater than the seasonal solar gain).

The product of the solar transmittance, utilization and the orientation factor results in the "ratio of useful solar to random incident solar", which is estimated to be 62% for the existing housing stock. This figure was verified with other published literature.

- The estimates of average liveable areas of dwellings were based on the representative house areas in Scanada's Canada II model[1]. The average window area was assumed to be 13% percent of average liveable areas, based on limited available surveys of actual houses. This was increased to 15% for new construction.

- The average degree-days for each province is taken to be the degree-days of the largest population centre of that province.

- Solar incidence from October to April were obtained from the Barakat study[2]. The incidence for "random orientation" was taken to be the average of the incidence for the north, east, south, and west directions.

- The blended heating efficiency was obtained from the Canada II model. Oil and gas heating were assumed to have approximately 60% seasonal efficiency and electric heating, 95% seasonal efficiency at point of use. The blended efficiency is therefore a weighted average of the electric and non-electric efficiencies, and is a function of the distribution of electric heating for each province.

- Statistics Canada reports the total quantity of oil, gas and electricity consumed by Canadian residences each year. The oil and gas consumptions are assumed to be entirely for space heating, even though there is some gas used for other end uses, e.g. cooking. However, in most provinces, the majority of electrical consumption in residences is for end uses other than space heating. Therefore, an estimate was developed of the percent of all electricity consumed by residences that is used directly for space heating.

- The residential housing stock for 1988 was based on the 1977 housing stock data from the Canada II model and completions statistics from 1978 to 1988 were taken from the Canadian Housing Statistics publication[3].

- An initial forecast of dwelling unit completions to the year 2010 was developed based on completion rates of the last ten years. This forecast over-predicted demographically based forecast[4, 5] by a factor of 1.2. Scanada's completions were based on the "net" increase in the housing stock by an average 2% (different rate for each province) as has been historically observed in Canada II model over a period of more than 40 years. Reference forecasts are in the neighbourhood of 160,000 completions per year. The last ten years has averaged over 200,000 completions. Our predictions show an average 188,000 completion per year.

A.2 Reconstruction of the Space Heating Load of the Total Housing Stock

An estimate of the total residential floor area was developed by multiplying the total residential dwelling units by the average floor area of that stock. The space heating index in megajoules per square meter per year was derived using the Canada II model. It was assumed that the average stock today has a heating index that is half way between the estimated heating index in 1978 and the upgraded index that was forecast by the Canada II model in 1978. The space heating index multiplied by the total floor area results in a total space heating estimate by province across Canada. This number was compared to the space heating demand statistics published by Statistics Canada.

On average, our reconstruction of the space heating demand fared well when compared to the published consumption statistics. Our 1988 estimate of total space heating demand was approximately 1,000 petajoules. This compares to 964 petajoules which was estimated using Statistics Canada's quarterly report on energy supply-demand. It will be noted that we had to deduct from the Statistics Canada reference an estimated amount of residential electricity that was non-space heating. The overall difference in estimates is 7% - a reasonable discrepancy given the assumptions made in this calculations. The estimates based on stock data and performance for Newfoundland, New Brunswick and Manitoba appear to be problematic overestimates. Statistics Canada's lack of accounting for wood heating in these provinces may account for the discrepancy. If so, the estimates based on stock data may be more believable than the consumption statistics. The estimate of total space heating requirements based on stock data were used for the rest of the calculations.

A.3 Reconstruction of Space Heating Load Attributable to Windows

The net Energy Performance Index (EPI) of the window was estimated using solar data, degree-days, window R-value, and an air leakiness index. The estimated solar gains, conduction and airchange losses were then numerically added to obtain the EPI. The net window EPI was negative for all provinces.

A.4 Ultimate Potential Performance of the Solar Aperture - General Assumptions

The following assumptions were made to estimate the ultimate EPI of windows (the solar apertures).

- The ultimate R-value assigned was an arbitrary RSI 1.76 (R-10). The technically feasible window of RSI 1.25 (R-7) was assumed.

- A leakage characteristic of .25 cubic metres per hour per metre of sash length at 75 Pascals will be the target tightness for new fixed windows once the new window omnibus standard being developed by CSA comes into use - CSA-A-440. That leakage characteristic was chosen to be the ultimate target for all windows, both fixed and moveable.

Note that for new construction, it is assumed that houses are already tight enough so that no credit was given for additional window tightness in that sector.

- A solar transmission of .7 was used to estimate the ultimate potential solar contribution.

- An orientation factor of 1.15 (out of a maximum 1.6) was chosen to reflect the typically skewed south facing window orientation of solar designs.

- It was estimated that additional mass could raise the solar utilization from 0.8 to become 0.9

Using the same methodology as used to estimate current window performance, the above assumptions were used to estimate ultimate window performance.

A.5 Reasonably Achievable Conservation Potential: General Assumptions

The following assumptions were made for the estimate of reasonable conservation potential:

- The R-value of current triple-glazed high performance windows (low E coatings and argon filled) RSI 1.0 (R-5.6) was assumed to be ready or near ready for widespread implementation.
- An average leakage characteristic of 1.65 (m3/h m) was assumed to be achievable - the mid-range of tightness in the CSA-A440 standard.
- A solar transmittance of .51 was chosen for high performance windows.
- A solar utilization of 0.85 was chosen
- The orientation factor was increased slightly to 1.11

The resulting ratio of useful solar to random incident solar is quite low at 45%. However, the net result is a break-even net EPI for the country, with positive EPI's in some areas of the country, negative in others.

A.6 Market Penetration Scenarios

Three scenarios were prepared to illustrate the possible impact of a conservation program designed to improve the performance of the solar aperture; these scenarios consisted of 10%, 30% and 70% total market penetrations by the year 2010. The results are shown for 5 year intervals, for each province.

A.7 References

1. Heating Canadian Houses: Current Performance and Potential for Improvement. By Scanada Consultants Limited for CMHC, 1979.
2. *Solar Heat Gains Through Windows in Canada*, DBR Paper #944, Division of Building Research, National Research Council of Canada, NRCC 18674, 1980.
3. Canadian Housing Statistics, CMHC, 1988.
4. Medium and Long Term Projections Of Housing Requirements in Canada. By Clayton Research Associates for CMHC, Dec 1987.
5. Inter-Fuel Substitution Demand Model - Long Term Outlook 1988-2010. EMR, May 31, 1989.

APPENDIX: B

ASSESSMENT OF PASSIVE SOLAR CONSERVATION POTENTIAL

EXISTING RESIDENTIAL (UP TO 1988)

ESTIMATE OF THE PASSIVE SOLAR CONSERVATION POTENTIAL IN CANADA: EXISTING RESIDENTIAL STOCK - UPTO 1988

GENERAL ASSUMPTIONS

Double Glazing R-value	0.320 m2 C/W
Leakage Characteristic	10 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage	4.481 m3/h m2 @ 5Pa
Solar transmittance	0.7
Mass effect: solar utilization	0.8
Orientation factor	1.1
Useful Solar/Random Incident	62 %

GEOGRAPHICALLY VARIABLE ASSUMPTIONS

	Ave. Livable Area m2	Glazing (% of livable)	Ave. Degree Days	Random Solar Incid. (MJ/m2)	Penetration Electric Space Heating	Blended Heating Effec.	Percent of prov utility that is space heating: only residential
Newfoundland	90	13	4800	1088	25	72	13
Prince Edward Island	90	13	4600	1422	15	69	8
Nova Scotia	90	13	4100	1465	15	69	8
New Brunswick	90	13	4700	1560	20	70	10
Quebec	100	13	4700	1476	55	83	28
Ontario	110	13	4100	1600	20	70	10
Manitoba	100	13	5900	1695	15	69	8
Saskatchewan	110	13	6000	1695	10	67	5
Alberta	110	13	5600	1600	10	67	5
British Columbia	110	13	3300	1000	20	70	10

HOUSING STOCK DATA - UPTO 1988

Province	singles	semi	row	walkups	highrise	total
Newfoundland	129,630	16,671	11,640	16,002	715	174,658
Prince Edward Island	34,931	3,370	2,363	5,898	0	46,562
Nova Scotia	222,587	24,547	6,491	55,137	5,726	314,488
New Brunswick	182,782	18,258	6,628	37,109	1,149	245,926
Quebec	1,069,487	432,452	176,300	703,056	113,690	2,494,985
Ontario	1,986,438	342,342	228,557	645,317	332,399	3,535,053
Manitoba	283,963	23,695	13,523	87,529	17,165	425,875
Saskatchewan	302,486	16,384	10,723	63,800	7,779	401,172
Alberta	585,177	58,419	62,114	166,604	43,045	915,359
British Columbia	775,017	55,060	56,099	199,547	52,259	1,137,982
Total	**5,572,498**	**991,198**	**574,438**	**1,979,999**	**573,927**	**9,692,060**

EXISTING RESIDENTIAL STOCK - 1988: RECONSTRUCTION OF THE SPACE HEATING LOAD OF THE TOTAL HOUSING STOCK

Province	Total Dwelling Units (millions)	Total Floor Area (Mega m2)	Space Heating Index (MJ/m2 yr)	Space Heating Index (kWh/m2 y)	Total Space Heating (PJ)	Stats Can Space Heating '87 (PJ)	Difference (%)
Newfoundland	0.175	16	1101	306	17	9	94 *
Prince Edward Island	0.047	4	1103	306	5	5	-5
Nova Scotia	0.314	28	919	255	26	27	-3
New Brunswick	0.246	22	1043	290	23	14	62 *
Quebec	2.495	249	817	227	204	147	38 *
Ontario	3.535	389	891	248	346	331	5
Manitoba	0.426	43	1418	394	60	36	67 *
Saskatchewan	0.401	44	1452	403	64	73	-12
Alberta	0.915	101	1281	356	129	160	-19
British Columbia	1.138	125	659	183	82	75	10
Total or Average	9.692	1,021	937	260	957	877	9

* - Large discrepency may be due to wood heating not accounted for by Statistics Canada.

RECONSTRUCTION OF THE SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET KPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Percent of total Heat loss
Newfoundland	0.175	2.0	670	-1080	-520	-929	1.9	-2.6	15
Prince Edward Island	0.047	0.5	876	-1035	-498	-657	0.7	-0.5	11
Nova Scotia	0.314	3.7	902	-923	-444	-464	4.8	-2.5	10
New Brunswick	0.246	2.9	961	-1058	-509	-605	3.9	-2.5	11
Quebec	2.495	32.4	909	-1058	-509	-657	35.4	-25.6	13
Ontario	3.535	50.6	986	-923	-444	-381	70.8	-27.3	8
Manitoba	0.426	5.5	1044	-1328	-639	-922	8.4	-7.4	12
Saskatchewan	0.401	5.7	1044	-1350	-649	-955	9.0	-8.2	13
Alberta	0.915	13.1	986	-1260	-606	-881	19.3	-17.3	13
British Columbia	1.138	16.3	616	-743	-357	-484	14.2	-11.2	14
Total or Average	9.692	132.8	918	-1010	-486	-578	168.5	-105.1	11

SUMMARY

Gross Window Loss	-274 PJ	Net Window Performance	-105 PJ
Solar Contribution	169 PJ	Solar Fraction	15 %

EXISTING RESIDENTIAL STOCK - 1988: ULTIMATE POTENTIAL PERFORMANCE OF THE SOLAR APERTURE

GENERAL ASSUMPTIONS

Ultimate opening R-value	1.8 m2 C/W
Leakage Characteristic:CSA A-440	0.25 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	0.112 m3/h m2 @ 5Pa
Solar transmittance	0.8
Mass effect: solar utilization	0.9
Orientation factor	1.15
Useful solar/Random Incident	82.8 %

RECONSTRUCTION OF SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr)			NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ	Percent of Total Loss (%)
			Solar Gain	Conduction Loss	Air Change Loss					
Newfoundland	0.175	2.0	901	-196	-13	692	2.5	2.0	5	26
Prince Edward Island	0.047	0.5	1177	-188	-12	977	0.9	0.8	1	28
Nova Scotia	0.314	3.7	1213	-168	-11	1034	6.5	5.6	8	31
New Brunswick	0.246	2.9	1292	-192	-13	1087	5.3	4.4	7	30
Quebec	2.495	32.4	1222	-192	-13	1017	47.6	39.6	65	32
Ontario	3.535	50.6	1325	-168	-11	1146	95.1	82.3	110	32
Manitoba	0.426	5.5	1403	-241	-16	1146	11.3	9.3	17	28
Saskatchewan	0.401	5.7	1403	-245	-16	1142	12.1	9.8	18	28
Alberta	0.915	13.1	1325	-229	-15	1081	26.0	21.2	38	30
British Columbia	1.138	16.3	828	-135	-9	684	19.1	15.8	27	33
Total or Average	**9.692**	**132.8**	**1234**	**-184**	**-12**	**1038**	**226.5**	**190.7**	**296**	**31**

SUMMARY

Gross Window Loss	-36 PJ
Solar Contribution	227 PJ
Net Window Performance	191 PJ
Solar Fraction	19 %

EXISTING RESIDENTIAL STOCK - 1988: REASONABLY ACHIEVABLE CONSERVATION POTENTIAL

GENERAL ASSUMPTIONS

Window R-value	0.8 m2 C/W
Leakage Characteristic	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.51
Mass effect: solar utilization	0.8
Orientation factor	1.11
Useful solar/Random Incident	45 %

RECONSTRUCTION OF SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Percent of Total Loss (%)
Newfoundland	0.175	2.0	493	-411	-130	-48	1.4	-0.1	2	14
Prince Edward Island	0.047	0.5	644	-394	-124	125	0.5	0.1	1	13
Nova Scotia	0.314	3.7	663	-351	-111	201	3.6	1.1	4	14
New Brunswick	0.246	2.9	706	-403	-127	177	2.9	0.7	3	14
Quebec	2.495	32.4	668	-403	-127	139	26.0	5.4	31	15
Ontario	3.535	50.6	725	-351	-111	262	52.0	18.8	46	13
Manitoba	0.426	5.5	768	-506	-160	102	6.2	0.8	8	14
Saskatchewan	0.401	5.7	768	-514	-162	91	6.6	0.8	9	14
Alberta	0.915	13.1	725	-480	-152	93	14.2	1.8	19	15
British Columbia	1.138	16.3	453	-283	-89	81	10.5	1.9	13	16
Total or Average	**9.692**	**132.8**	**675**	**-385**	**-122**	**169**	**123.9**	**31.3**	**136**	**14**

SUMMARY

Gross Window Loss	-93 PJ
Solar Contribution	124 PJ
Net Window Performance	31 PJ
Solar Fraction	11 %

EXISTING RESIDENTIAL STOCK - 1988: MARKET PENETRATION SCENARIOS

Scenario "A": 10% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential	Year -->	1995	2000	2005	2010
Province	(PJ)	Market Penetration % -->	1	4	7	10
Newfoundland	2		0.02	0.10	0.17	0.2
Prince Edward Island	1		0.01	0.02	0.04	0.1
Nova Scotia	4		0.04	0.14	0.25	0.4
New Brunswick	3		0.03	0.13	0.22	0.3
Quebec	31		0.31	1.24	2.17	3.1
Ontario	46		0.46	1.85	3.23	4.6
Manitoba	8		0.08	0.33	0.58	0.8
Saskatchewan	9		0.09	0.36	0.63	0.9
Alberta	19		0.19	0.76	1.34	1.9
British Columbia	13		0.13	0.52	0.91	1.3
Total or Average	136		1.4	5.5	9.6	13.6

Scenario "B": 30% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential	Year -->	1995	2000	2005	2010
Province	(PJ)	Market Penetration % -->	3	12	21	30
Newfoundland	2		0.07	0.30	0.5	0.7
Prince Edward Island	1		0.02	0.07	0.1	0.2
Nova Scotia	4		0.11	0.43	0.7	1.1
New Brunswick	3		0.10	0.38	0.7	1.0
Quebec	31		0.93	3.72	6.5	9.3
Ontario	46		1.39	5.54	9.7	13.9
Manitoba	8		0.25	0.99	1.7	2.5
Saskatchewan	9		0.27	1.08	1.9	2.7
Alberta	19		0.57	2.29	4.0	5.7
British Columbia	13		0.39	1.57	2.7	3.9
Total or Average	136		4.1	16.4	28.7	40.9

Scenario "C": 70% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential (PJ)	Year -->	1995	2000	2005	2010
Province		Market Penetration % -->	7	28	49	70
Newfoundland	2		0.17	0.7	1.2	1.7
Prince Edward Island	1		0.04	0.2	0.3	0.4
Nova Scotia	4		0.25	1.0	1.7	2.5
New Brunswick	3		0.22	0.9	1.6	2.2
Quebec	31		2.17	8.7	15.2	21.7
Ontario	46		3.23	12.9	22.6	32.3
Manitoba	8		0.58	2.3	4.1	5.8
Saskatchewan	9		0.63	2.5	4.4	6.3
Alberta	19		1.34	5.4	9.4	13.4
British Columbia	13		0.91	3.7	6.4	9.1
Total or Average	**136**		**9.6**	**38.2**	**66.9**	**95.5**

APPENDIX: C

ASSESSMENT OF PASSIVE SOLAR CONSERVATION POTENTIAL

NEW RESIDENTIAL (1989-2010)

ESTIMATE OF THE PASSIVE SOLAR CONSERVATION POTENTIAL IN CANADA: NEW RESIDENTIAL STOCK: 1989 - 2010

GENERAL ASSUMPTIONS

Double glazing R-value	0.320 m2 C/W
Leakage Characteristic	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.7
Mass Effect: solar utilization	0.8
Orientation factor	1.1
Useful Solar/Random Incident	62 %

GEOGRAPHICALLY VARIABLE ASSUMPTIONS

	Ave. Livable Area m2	Glazing (% of livable)	Ave. Degree Days	Random Solar Incid. (MJ/m2)	Penetration of elect. space heat	Blended Heating Effeciency.
Newfoundland	100	15	4800	1088	30	79
Prince Edward Island	100	15	4600	1422	20	76
Nova Scotia	100	15	4100	1465	20	76
New Brunswick	100	15	4700	1560	50	85
Quebec	110	15	4700	1476	75	93
Ontario	120	15	4100	1600	25	78
Manitoba	110	15	5900	1695	25	78
Saskatchewan	120	15	6000	1695	10	73
Alberta	120	15	5600	1600	10	73
British Columbia	120	15	3300	1000	30	79

NEW HOUSING STOCK DATA: 1989 - 2010

Province	singles	semi	row	walkups	highrise	total
Newfoundland	48,711	2,003	4,496	10,031	1,272	66,514
Prince Edward Island	10,494	688	5,066	3,821	0	20,069
Nova Scotia	69,580	7,086	279	30,855	3,828	111,628
New Brunswick	66,605	1,267	1,094	11,221	722	80,909
Quebec	458,876	44,748	18,533	364,757	109,051	995,965
Ontario	670,001	89,520	199,135	198,766	190,793	1,348,215
Manitoba	60,850	6,228	7,368	37,814	10,556	122,815
Saskatchewan	79,814	7,441	6,625	74,949	14,668	183,497
Alberta	276,315	34,841	126,488	124,927	139,660	702,230
British Columbia	317,339	17,320	87,088	69,789	5,831	497,367
Total	**2,058,585**	**211,141**	**456,172**	**926,932**	**476,379**	**4,129,209**
Average Completions	**93,572**	**9,597**	**20,735**	**42,133**	**21,654**	**187,691**

NEW RESIDENTIAL STOCK: 1989 - 2010: RECONSTRUCTION OF THE SPACE HEATING LOAD OF THE TOTAL HOUSING STOCK

Province	Total Dwelling Units (millions)	Total Floor Area (Mega m2)	Space Heating Index (MJ/m2 yr)	Space Heating Index (kWh/m2 y)	Total Space Heating (PJ)
Newfoundland	0.067	7	814	226	5
Prince Edward Island	0.020	2	914	254	2
Nova Scotia	0.112	11	681	189	8
New Brunswick	0.081	8	737	205	6
Quebec	0.996	110	606	168	66
Ontario	1.348	162	624	173	101
Manitoba	0.123	14	1009	280	14
Saskatchewan	0.183	22	1016	282	22
Alberta	0.702	84	902	251	76
British Columbia	0.497	60	448	125	27
Total or Average	**4.129**	**479**	**683**	**190**	**327**

RECONSTRUCTION OF THE SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Percent of total Heat loss
Newfoundland	0.067	1.0	670	-1080	-130	-540	0.8	-0.7	13
Prince Edward Island	0.020	0.3	876	-1035	-124	-284	0.3	-0.1	6
Nova Scotia	0.112	1.7	902	-923	-111	-131	2.0	-0.3	4
New Brunswick	0.081	1.2	961	-1058	-127	-224	1.4	-0.3	5
Quebec	0.996	16.4	909	-1058	-127	-275	16.2	-4.9	7
Ontario	1.348	24.3	986	-923	-111	-48	30.9	-1.5	1
Manitoba	0.123	2.0	1044	-1328	-160	-443	2.7	-1.2	8
Saskatchewan	0.183	3.3	1044	-1350	-162	-468	4.7	-2.1	9
Alberta	0.702	12.6	986	-1260	-152	-426	17.1	-7.4	10
British Columbia	0.497	9.0	616	-743	-89	-216	7.0	-2.4	9
Total or Average	**4.129**	**71.8**	**919**	**-1028**	**-124**	**-232**	**83.1**	**-20.9**	**6**

SUMMARY

Gross Window Loss	-83 PJ
Solar Contribution	83 PJ
Net Window Performance	0 PJ
Solar Fraction	20 %

NEW RESIDENTIAL STOCK: 1989 - 2010: ULTIMATE POTENTIAL PERFORMANCE OF THE SOLAR APERTURE

GENERAL ASSUMPTIONS

Ultimate opening R-value	1.8 m2 C/W
Leakage Characteristic:CSA A-440	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.8
Mass Effect: solar utilization	0.9
Orientation factor	1.25
Useful solar/Random Incident	90 %

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Percent of Total Loss (%)
Newfoundland	0.067	1.0	979	-196	-130	653	1.2	0.8	2	28
Prince Edward Island	0.020	0.3	1280	-188	-124	967	0.5	0.4	0	27
Nova Scotia	0.112	1.7	1319	-168	-111	1040	2.9	2.3	3	34
New Brunswick	0.081	1.2	1404	-192	-127	1085	2.0	1.5	2	31
Quebec	0.996	16.4	1328	-192	-127	1009	23.6	17.9	23	34
Ontario	1.348	24.3	1440	-168	-111	1161	45.1	36.4	38	38
Manitoba	0.123	2.0	1526	-241	-160	1124	4.0	2.9	4	30
Saskatchewan	0.183	3.3	1526	-245	-162	1118	6.9	5.1	7	32
Alberta	0.702	12.6	1440	-229	-152	1059	24.9	18.3	26	34
British Columbia	0.497	9.0	900	-135	-89	676	10.2	7.7	10	38
Total or Average	**4.129**	**71.8**	**1342**	**-187**	**-124**	**1032**	**121.4**	**93.3**	**114**	**35**

SUMMARY

Gross Window Loss	-28 PJ
Solar Contribution	121 PJ
Net Window Performance	93 PJ
Solar Fraction	27 %

NEW RESIDENTIAL STOCK: 1989 - 2010: REASONABLY ACHIEVABLE CONSERVATION POTENTIAL

GENERAL ASSUMPTIONS

Super Window R-value	0.8 m2 C/W
Leakage Characteristic	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.51
Mass effect: solar utilization	0.85
Orientation factor	1.15
Useful solar/Random Incident	50 %

Province	Total Dwelling Units (millions)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Percent of Total Loss (%)
Newfoundland	0.067	1.0	542	-411	-130	1	0.7	0.0	0.7	13
Prince Edward Island	0.020	0.3	709	-394	-124	190	0.3	0.1	0.2	10
Nova Scotia	0.112	1.7	730	-351	-111	268	1.6	0.6	0.9	12
New Brunswick	0.081	1.2	778	-403	-127	248	1.1	0.4	0.7	11
Quebec	0.996	16.4	736	-403	-127	206	13.1	3.7	8.6	13
Ontario	1.348	24.3	798	-351	-111	335	25.0	10.5	12.0	12
Manitoba	0.123	2.0	845	-506	-160	180	2.2	0.5	1.6	12
Saskatchewan	0.183	3.3	845	-514	-162	169	3.8	0.8	2.9	13
Alberta	0.702	12.6	798	-480	-152	166	13.8	2.9	10.3	13
British Columbia	0.497	9.0	499	-283	-89	126	5.6	1.4	3.9	14
Total or Average	**4.129**	**71.8**	**743**	**-391**	**-124**	**229**	**67.2**	**20.7**	**41.6**	**13**

SUMMARY

Gross Window Loss	-46 PJ
Solar Contribution	67 PJ
Net Window Performance	21 PJ
Solar Fraction	17 %

NEW RESIDENTIAL STOCK: 1989 - 2010: MARKET PENETRATION SCENARIOS

Scenario "A": 10% market penetration

Province	Achievable Conservation Potential (PJ)		CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
		Market Penetration % -->	1	4	7	10
Newfoundland	0.7		0.01	0.03	0.05	0.07
Prince Edward Island	0.2		0.00	0.01	0.01	0.02
Nova Scotia	0.9		0.01	0.04	0.06	0.09
New Brunswick	0.7		0.01	0.03	0.05	0.07
Quebec	8.6		0.09	0.34	0.60	0.86
Ontario	12.0		0.12	0.48	0.84	1.20
Manitoba	1.6		0.02	0.07	0.11	0.16
Saskatchewan	2.9		0.03	0.12	0.20	0.29
Alberta	10.3		0.10	0.41	0.72	1.03
British Columbia	3.9		0.04	0.16	0.27	0.39
Total or Average	41.6		0.4	1.7	2.9	4.2

Scenario "B": 30% market penetration

Province	Achievable Conservation Potential (PJ)		CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
		Market Penetration % -->	3	12	21	30
Newfoundland	0.7		0.02	0.08	0.14	0.20
Prince Edward Island	0.2		0.01	0.02	0.04	0.06
Nova Scotia	0.9		0.03	0.11	0.18	0.26
New Brunswick	0.7		0.02	0.08	0.14	0.20
Quebec	8.6		0.26	1.03	1.80	2.57
Ontario	12.0		0.36	1.44	2.52	3.60
Manitoba	1.6		0.05	0.20	0.34	0.49
Saskatchewan	2.9		0.09	0.35	0.61	0.86
Alberta	10.3		0.31	1.23	2.15	3.08
British Columbia	3.9		0.12	0.47	0.81	1.16
Total or Average	41.6		1.2	5.0	8.7	12.5

Scenario "C": 70% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential	Year -->	1995	2000	2005	2010
Province	(PJ)	Market Penetration % -->	7	28	49	70
Newfoundland	0.7		0.05	0.19	0.33	0.48
Prince Edward Island	0.2		0.01	0.05	0.09	0.13
Nova Scotia	0.9		0.06	0.25	0.43	0.62
New Brunswick	0.7		0.05	0.19	0.33	0.47
Quebec	8.6		0.60	2.39	4.19	5.99
Ontario	12.0		0.84	3.36	5.88	8.40
Manitoba	1.6		0.11	0.46	0.80	1.14
Saskatchewan	2.9		0.20	0.81	1.41	2.02
Alberta	10.3		0.72	2.87	5.02	7.18
British Columbia	3.9		0.27	1.09	1.90	2.72
Total or Average	**41.6**		**2.9**	**11.7**	**20.4**	**29.1**

APPENDIX: D

ASSESSMENT OF PASSIVE SOLAR CONSERVATION POTENTIAL

EXISTING NON RESIDENTIAL OR COMMERCIAL (UP TO 1988)

ESTIMATE OF THE PASSIVE SOLAR CONSERVATION POTENTIAL IN CANADA: EXISTING COMMERCIAL STOCK - UP TO 1988

GENERAL ASSUMPTIONS

Average Glazing R-value	0.250	m2 C/W
Leakage Characteristic	10	m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5	m/m2
Net leakage	4.481	m3/h m2 @ 5Pa
Solar transmittance	0.7	
Summer Shading Factor	0.8	
Mass effect: solar utilization	0.75	
Orientation factor	1.10	
Solar Gain/Random Incident	58	%
Air-conditioning performance	2.7	

GEOGRAPHICALLY VARIABLE ASSUMPTIONS

	Heating Degree Days	Cooling Degree Days	Random Heating Seas. Solar Incidence (MJ/m2)	Random C.S. Solar Incid (MJ/m2)	Heating Effic. (%)	Percent Oil & Gas Space heat
Newfoundland	4800	11	1088	1631	70	80
Prince Edward Island	4600	25	1422	1732	70	80
Nova Scotia	4100	39	1465	1832	70	80
New Brunswick	4700	62	1560	1950	70	80
Quebec	4700	84	1476	2067	80	80
Ontario	4100	167	1600	2234	70	80
Manitoba	5900	145	1695	2190	70	80
Saskatchewan	6000	66	1695	2221	70	80
Alberta	5600	66	1600	2252	70	80
British Columbia	3300	65	1000	2022	70	80

Reference distribution of the commercial building stock 1981 - F. STEELS - DBR

	offices	stores	schools	warehouses	misc	total
No. of Buildings	137,800	72,200	46,700	61,100	199,200	517,000
Average Size (m2)	900	900	1,200	900	1,000	966

Estimated proportion of glazing to floor area (%)

	offices	stores	schools	warehouses	misc	average
All regions	15	12	16	1	10	11.2

Estimated proportion of total floor area that is air conditioned (%)

	offices	stores	schools	warehouses	misc	average
All regions	85	85	15	1	50	53.9

Reference space heating and cooling indeces for Ontario (using Ontario Hydro Commercial Energy Manual - Applications)

	offices	stores	schools	warehouses	misc	total
Heating (kWh/m2 y)	220	280	180	120	200	205
Cooling (kWh/m2 y)	55	70	11	3	50	45

COMMERCIAL BUILDING STOCK - 1988

Province	offices	stores	schools	warehouses	misc comm**	total	Total floor area (million m2)
Newfoundland	2,832	1,484	960	1,256	4,095	10,627	10
Prince Edward Island	756	396	256	335	1,093	2,838	3
Nova Scotia	5,066	2,654	1,717	2,246	7,323	19,006	18
New Brunswick	3,934	2,061	1,333	1,744	5,686	14,758	14
Quebec	40,505	21,222	13,727	17,960	58,552	151,965	147
Ontario	57,322	30,034	19,426	25,416	82,863	215,061	208
Manitoba	6,720	3,521	2,277	2,980	9,715	25,213	24
Saskatchewan	6,552	3,433	2,220	2,905	9,471	24,580	24
Alberta	15,936	8,350	5,401	7,066	23,037	59,789	58
British Columbia	18,666	9,780	6,326	8,277	26,984	70,033	68
Total	158,289	82,935	53,644	70,185	228,819	593,872	573

** Miscelaneous Commercial Building Stock

Province	Factory	Hotels	Garages	Theaters	Churches	Hospitals	Other Inst	Misc.	Total Misc. Comm
Newfoundland	1,159	516	225	500	57	876	409	352	4,095
Prince Edward Island	309	138	60	133	15	234	109	94	1,093
Nova Scotia	2,072	923	403	893	103	1,567	732	630	7,323
New Brunswick	1,609	716	313	694	80	1,217	569	489	5,686
Quebec	16,570	7,378	3,220	7,143	820	12,530	5,855	5,035	58,552
Ontario	23,450	10,441	4,557	10,109	1,160	17,733	8,286	7,126	82,863
Manitoba	2,749	1,224	534	1,185	136	2,079	971	835	9,715
Saskatchewan	2,680	1,193	521	1,155	133	2,027	947	814	9,471
Alberta	6,519	2,903	1,267	2,810	323	4,930	2,304	1,981	23,037
British Columbia	7,636	3,400	1,484	3,292	378	5,775	2,698	2,321	26,984
Total	64,756	28,831	12,585	27,916	3,203	48,967	22,882	19,678	228,819

EXISTING COMMERCIAL STOCK - 1988

RECONSTRUCTION OF THE SPACE HEATING LOAD OF THE TOTAL COMMERCIAL STOCK

Province	Total Buildings (thousands)	Total Floor Area (Mega m2)	Space Heating Index (MJ/m2 yr)	Space Heating Index (kWh/m2 y)	Total Space Heating (PJ)	Stats Can Space Heating '87 (PJ)	Difference (%)
Newfoundland	11	10	865	240	9	13	-30
Prince Edward Island	3	3	829	230	2	3	-11
Nova Scotia	19	18	739	205	14	20	-32
New Brunswick	15	14	847	235	12	11	14
Quebec	152	147	741	206	109	89	22
Ontario	215	208	739	205	153	162	-5
Manitoba	25	24	1063	295	26	25	4
Saskatchewan	25	24	1081	300	26	26	-3
Alberta	60	58	1009	280	58	88	-33
British Columbia	70	68	595	165	40	56	-28
Total or Average	**594**	**573**	**783**	**217**	**449**	**491**	**-9**

RECONSTRUCTION OF THE SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Percent of total Heat loss
Newfoundland	11	1.1	628	-1382	-520	-1274	1.0	-2.1	24
Prince Edward Island	3	0.3	821	-1325	-498	-1001	0.4	-0.4	19
Nova Scotia	19	2.1	846	-1181	-444	-779	2.5	-2.3	17
New Brunswick	15	1.6	901	-1354	-509	-961	2.1	-2.2	18
Quebec	152	16.4	852	-1354	-509	-1010	17.5	-20.7	19
Ontario	215	23.2	924	-1181	-444	-701	30.7	-23.2	15
Manitoba	25	2.7	979	-1699	-639	-1359	3.8	-5.3	20
Saskatchewan	25	2.7	979	-1728	-649	-1399	3.7	-5.3	21
Alberta	60	6.5	924	-1613	-606	-1295	8.5	-11.9	21
British Columbia	70	7.6	578	-950	-357	-730	6.2	-7.9	20
Total or Average	**594**	**64.1**	**861**	**-1295**	**-487**	**-921**	**76.4**	**-81.4**	**18**

SUMMARY

Gross Window Loss	-158 PJ	Net Window Performance	-81 PJ
Solar Contribution	76 PJ	Solar Fraction	15 %

EXISTING COMMERCIAL STOCK - 1988

RECONSTRUCTION OF THE SPACE COOLING LOAD OF THE TOTAL COMMERCIAL STOCK

Province	Total Buildings (thousands)	Total Floor Area (Mega m2)	Space Cooling Index (MJ/m2 yr)	Space Cooling Index (kWh/m2 y)	Total Space Cooling (PJ)	Stats Can Space Cooling '87 (PJ)*	Difference (%)
Newfoundland	11	10.3	118	33	0.7	0.9	-24
Prince Edward Island	3	2.7	126	35	0.2	0.1	35
Nova Scotia	19	18.4	133	37	1.3	1.2	8
New Brunswick	15	14.3	142	39	1.1	1.1	3
Quebec	152	146.7	150	42	11.9	14.7	-19
Ontario	215	207.7	162	45	18.2	19.3	-6
Manitoba	25	24.3	159	44	2.1	1.9	11
Saskatchewan	25	23.7	161	45	2.1	1.9	11
Alberta	60	57.7	164	45	5.1	5.2	-3
British Columbia	70	67.6	147	41	5.4	5.4	-1
Total or Average	594	573.5	155	43	47.9	51.7	-7

* - 15% of the reported commercial electrical consumption is assumed to be for space cooling

RECONSTRUCTION OF THE SPACE COOLING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET KPI	Solar Load (PJ)	Total Window Gain (PJ)	Percent of total Cooling Load
Newfoundland	11	1.1	279	1.2	0.4	281	0.2	0.2	27
Prince Edward Island	3	0.3	296	2.7	1.0	300	0.0	0.0	27
Nova Scotia	19	2.1	313	4.2	1.6	319	0.3	0.4	27
New Brunswick	15	1.6	334	6.6	2.5	343	0.3	0.3	27
Quebec	152	16.4	354	9.0	3.4	366	3.1	3.2	27
Ontario	215	23.2	382	17.8	6.7	407	4.8	5.1	28
Manitoba	25	2.7	375	15.5	5.8	396	0.6	0.6	28
Saskatchewan	25	2.7	380	7.0	2.6	390	0.5	0.6	27
Alberta	60	6.5	385	7.0	2.6	395	1.3	1.4	27
British Columbia	70	7.6	346	6.9	2.6	355	1.4	1.4	27
Total or Average	594	64.1	365	11.5	4.3	381	12.6	13.2	27

SUMMARY

Summer Solar Gains 13 PJ Total Window Cooling 13 PJ

EXISTING COMMERCIAL STOCK - 1988

ULTIMATE POTENTIAL PERFORMANCE OF THE SOLAR APERTURE

GENERAL ASSUMPTIONS

Ultimate opening R-value	1.8	m2 C/W
Leakage Characteristic:CSA A-440	0.25	m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5	m/m2
Net leakage characteristic	0.112	m3/h m2 @ 5Pa
Solar transmittance	0.8	
Summer Shading Factor	0.7	
Mass effect: solar utilization	0.8	
Orientation factor	1.11	
Solar Gain/Random Incident	71	%

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Percent of Total Loss (%)
Newfoundland	11	1.1	773	-196	-13	564	1.3	0.9	3	34
Prince Edward Island	3	0.3	1010	-188	-12	810	0.4	0.4	1	35
Nova Scotia	19	2.1	1041	-168	-11	862	3.1	2.5	5	35
New Brunswick	15	1.6	1108	-192	-13	903	2.5	2.1	4	35
Quebec	152	16.4	1049	-192	-13	844	21.5	17.3	38	35
Ontario	215	23.2	1137	-168	-11	958	37.7	31.8	55	36
Manitoba	25	2.7	1204	-241	-16	947	4.7	3.7	9	35
Saskatchewan	25	2.7	1204	-245	-16	942	4.6	3.6	9	35
Alberta	60	6.5	1137	-229	-15	892	10.5	8.2	20	35
British Columbia	70	7.6	710	-135	-9	566	7.7	6.1	14	35
Total or Average	**594**	**64.1**	**1059**	**-184**	**-12**	**863**	**93.9**	**76.6**	**158**	**35**

SUMMARY

Gross Window Loss	-17 PJ
Solar Contribution	94 PJ
Net Window Performance	77 PJ
Solar Fraction	17 %

CORRESPONDING COOLING PERFORMANCE OF WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET KPI	Solar Load (PJ)	Total Window Gain (PJ)	Conservation Potential (PJ)
Newfoundland	11	1.1	300	0.2	0.0	301	0.2	0.2	-0.0
Prince Edward Island	3	0.3	319	0.4	0.0	319	0.1	0.1	-0.0
Nova Scotia	19	2.1	337	0.6	0.0	338	0.4	0.4	-0.0
New Brunswick	15	1.6	359	0.9	0.1	360	0.3	0.3	-0.0
Quebec	152	16.4	381	1.3	0.1	382	3.4	3.4	-0.1
Ontario	215	23.2	411	2.5	0.2	414	5.2	5.2	-0.1
Manitoba	25	2.7	403	2.2	0.1	406	0.6	0.6	-0.0
Saskatchewan	25	2.7	409	1.0	0.1	410	0.6	0.6	-0.0
Alberta	60	6.5	415	1.0	0.1	416	1.4	1.4	-0.1
British Columbia	70	7.6	372	1.0	0.1	373	1.5	1.5	-0.1
Total or Average	**594**	**64**	**393**	**1.6**	**0.1**	**395**	**13.6**	**13.6**	**-0.5**

SUMMARY

Summer Solar Gains	14 PJ
Total Window Cooling	14 PJ

EXISTING COMMERCIAL STOCK - 1988

REASONABLY ACHIEVABLE CONSERVATION POTENTIAL

GENERAL ASSUMPTIONS

Super Window R-value	0.8 m2 C/W
Leakage Characteristic	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.51
Summer Shading Factor	0.75
Mass effect: solar utilization	0.75
Orientation factor	1.10
Solar Gain/Random Incident	42 %

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET KPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Conservatio Potential (%)
Newfoundland	11	1.1	458	-411	-130	-83	0.8	-0.1	2	22
Prince Edward Island	3	0.3	598	-394	-124	80	0.3	0.0	0	21
Nova Scotia	19	2.1	616	-351	-111	154	1.8	0.5	3	20
New Brunswick	15	1.6	656	-403	-127	126	1.5	0.3	2	21
Quebec	152	16.4	621	-403	-127	91	12.7	1.9	23	21
Ontario	215	23.2	673	-351	-111	211	22.3	7.0	30	20
Manitoba	25	2.7	713	-506	-160	48	2.8	0.2	5	21
Saskatchewan	25	2.7	713	-514	-162	37	2.7	0.1	5	21
Alberta	60	6.5	673	-480	-152	42	6.2	0.4	12	21
British Columbia	70	7.6	421	-283	-89	49	4.5	0.5	8	21
Total or Average	**594**	**64.1**	**627**	**-385**	**-122**	**120**	**55.6**	**10.7**	**92**	**21**

SUMMARY

Gross Window Loss	-45 PJ
Solar Contribution	56 PJ
Net Window Performance	11 PJ
Solar Fraction	11 %

CORRESPONDING COOLING PERFORMANCE OF THE WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET EPI	Solar Load (PJ)	Total Window Gain (PJ)	Conservation Potential (PJ)	Conservation Potential (PJ)
Newfoundland	11	1	191	0.3	0.1	191	0.1	0.1	0.1	32
Prince Edward Island	3	0	202	0.8	0.3	203	0.0	0.0	0.0	32
Nova Scotia	19	2	214	1.2	0.4	216	0.2	0.2	0.1	32
New Brunswick	15	2	228	2.0	0.6	230	0.2	0.2	0.1	33
Quebec	152	16	242	2.7	0.8	245	2.1	2.2	1.1	33
Ontario	215	23	261	5.3	1.7	268	3.3	3.4	1.7	34
Manitoba	25	3	256	4.6	1.5	262	0.4	0.4	0.2	34
Saskatchewan	25	3	260	2.1	0.7	262	0.4	0.4	0.2	33
Alberta	60	6	263	2.1	0.7	266	0.9	0.9	0.4	33
British Columbia	70	8	236	2.0	0.6	239	1.0	1.0	0.5	33
Total or Average	**594**	**64**	**249**	**3.4**	**1.1**	**254**	**8.6**	**8.8**	**4.4**	**33**

SUMMARY

Summer Solar Gains	9 PJ
Total Window Cooling	9 PJ

EXISTING COMMERCIAL STOCK - 1988

MARKET PENETRATION SCENARIOS

Scenario "A": 10% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential (PJ)	Year -->	1995	2000	2005	2010
Province		Market Penetration % -->	1	4	7	10
Newfoundland	2		0.02	0.08	0.14	0.20
Prince Edward Island	0		0.00	0.02	0.03	0.05
Nova Scotia	3		0.03	0.11	0.20	0.28
New Brunswick	3		0.03	0.10	0.18	0.26
Quebec	24		0.24	0.95	1.66	2.37
Ontario	32		0.32	1.28	2.24	3.20
Manitoba	6		0.06	0.23	0.40	0.57
Saskatchewan	6		0.06	0.23	0.39	0.56
Alberta	13		0.13	0.51	0.89	1.28
British Columbia	9		0.09	0.36	0.62	0.89
Total or Average	97		1.0	3.9	6.8	9.7

Scenario "B": 30% market penetration

			CUMULATIVE CONSERVATION (PJ)			
	Achievable Conservation Potential (PJ)	Year -->	1995	2000	2005	2010
Province		Market Penetration % -->	3	12	21	30
Newfoundland	2		0.06	0.24	0.42	0.60
Prince Edward Island	0		0.01	0.06	0.10	0.15
Nova Scotia	3		0.09	0.34	0.60	0.85
New Brunswick	3		0.08	0.31	0.54	0.77
Quebec	24		0.71	2.84	4.97	7.10
Ontario	32		0.96	3.84	6.72	9.60
Manitoba	6		0.17	0.68	1.19	1.70
Saskatchewan	6		0.17	0.68	1.18	1.69
Alberta	13		0.38	1.53	2.68	3.83
British Columbia	9		0.27	1.07	1.87	2.67
Total or Average	97		2.9	11.6	20.3	29.0

Scenario "C": 70% market penetration

Province	Achievable Conservation Potential (PJ)		CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
		Market Penetration % -->	7	28	49	70
Newfoundland	2		0.14	0.56	0.98	1.40
Prince Edward Island	0		0.03	0.14	0.24	0.34
Nova Scotia	3		0.20	0.80	1.40	1.99
New Brunswick	3		0.18	0.72	1.26	1.80
Quebec	24		1.66	6.62	11.59	16.56
Ontario	32		2.24	8.96	15.67	22.39
Manitoba	6		0.40	1.59	2.78	3.97
Saskatchewan	6		0.39	1.58	2.76	3.94
Alberta	13		0.89	3.58	6.26	8.95
British Columbia	9		0.62	2.49	4.36	6.22
Total or Average	**97**		**6.8**	**27.0**	**47.3**	**67.6**

APPENDIX: E

ASSESSMENT OF PASSIVE SOLAR CONSERVATION POTENTIAL

NEW NON RESIDENTIAL OR COMMERCIAL (1989-2010)

ESTIMATE OF THE PASSIVE SOLAR CONSERVATION POTENTIAL IN CANADA: NEW COMMERCIAL STOCK: 1989 - 2010

GENERAL ASSUMPTIONS

Average Glazing R-value	0.300 m2 C/W
Leakage Characteristic	10 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage	4.481 m3/h m2 @ 5Pa
Solar transmittance	0.7
Summer Shading Factor	0.8
Mass effect: solar utilization	0.8
Orientation factor	1.07
Solar Gain/Random Incident	60 %
Air-conditioning performance	2.7

GEOGRAPHICALLY VARIABLE ASSUMPTIONS

	Heating Degree Days	Cooling Degree Days	Random Heating Seas. Solar Incidence (MJ/m2)	Random C.S. Solar Incid (MJ/m2)	Heating Effic. (%)	Percent Oil & Gas Space heat
Newfoundland	4800	11	1088	1631	70	80
Prince Edward Island	4600	25	1422	1732	70	80
Nova Scotia	4100	39	1465	1832	70	80
New Brunswick	4700	62	1560	1950	70	80
Quebec	4700	84	1476	2067	80	80
Ontario	4100	167	1600	2234	70	80
Manitoba	5900	145	1695	2190	70	80
Saskatchewan	6000	66	1695	2221	70	80
Alberta	5600	66	1600	2252	70	80
British Columbia	3300	65	1000	2022	70	80

Reference distribution of the commercial building stock 1981 - F. STEELS - DBR

	offices	stores	schools	warehouses	misc	total
No. of Buildings	137,800	72,200	46,700	61,100	199,200	517,000
Average Size (m2)	900	900	1,200	900	1,000	966

Estimated proportion of glazing to floor area (%)

	offices	stores	schools	warehouses	misc	average
All regions	15	12	16	1	10.	11.2

Estimated proportion of total floor area that is air conditioned (%)

	offices	stores	schools	warehouses	misc	average
All regions	95	95	25	1	75	68.8

Reference space heating and cooling indeces for Ontario (using Ontario Hydro Commercial Energy Manual - Applications)

	offices	stores	schools	warehouses	misc	total
Heating (kWh/m2 y)	220	280	180	120	200	205
Cooling (kWh/m2 y)	55	70	11	3	50	45

COMMERCIAL BUILDING STOCK: 1989 - 2010

Province	offices	stores	schools	warehouses	misc comm**	total	total floor area (million m2)
Newfoundland	1326	695	450	588	1917	4,976	4
Prince Edward Island	359	188	122	159	519	1,348	1
Nova Scotia	2237	1172	758	992	3234	8,394	8
New Brunswick	1629	853	552	722	2355	6,111	6
Quebec	19139	10028	6486	8486	27666	71,805	69
Ontario	26817	14051	9088	11890	38766	100,612	97
Manitoba	2433	1275	824	1079	3517	9,128	9
Saskatchewan	3251	1704	1102	1442	4700	12,199	12
Alberta	12209	6397	4138	5413	17649	45,806	44
British Columbia	9595	5027	3252	4254	13871	35,999	35
Total	**78,996**	**41,390**	**26,771**	**35,026**	**114,194**	**296,377**	**285**
Average completions/yr	**3762**	**1971**	**1275**	**1668**	**5438**	**14113**	**14**

** **Miscelaneous Commercial Buildings**

Province	Factory	Hotels	Garages	Theaters	Churches	Hospitals	Other Inst	Misc.	Total Misc Comm
Newfoundland	542	241	105	234	27	410	192	165	1,917
Prince Edward Island	147	65	29	63	7	111	52	45	519
Nova Scotia	918	409	178	396	45	694	324	279	3,234
New Brunswick	668	297	130	288	33	505	236	203	2,355
Quebec	7,806	3,475	1,517	3,365	386	5,903	2,758	2,372	27,666
Ontario	10,972	4,885	2,132	4,730	543	8,297	3,877	3,334	38,766
Manitoba	992	442	193	428	49	750	350	301	3,517
Saskatchewan	1,331	593	259	574	66	1,007	470	405	4,700
Alberta	4,997	2,225	971	2,154	247	3,779	1,766	1,518	17,649
British Columbia	3,917	1,744	761	1,689	194	2,962	1,384	1,190	13,871
Total	**32,290**	**14,376**	**6,275**	**13,920**	**1,597**	**24,417**	**11,410**	**9,812**	**114,194**
Average completion/yr	**1,538**	**685**	**299**	**663**	**76**	**1,163**	**543**	**467**	**5,438**

NEW COMMERCIAL STOCK: 1989 - 2010

RECONSTRUCTION OF THE SPACE HEATING LOAD OF THE TOTAL COMMERCIAL STOCK

Province	Total Buildings (thousands)	Total Floor Area (Mega m2)	Space Heating Index (MJ/m2 yr)	Space Heating Index (kWh/m2 y)	Total Space Heating (PJ)
Newfoundland	5	4	865	240	3
Prince Edward Island	1	1	829	230	1
Nova Scotia	8	8	739	205	6
New Brunswick	6	6	847	235	5
Quebec	72	69	741	206	51
Ontario	101	97	739	205	72
Manitoba	9	9	1063	295	9
Saskatchewan	12	12	1081	300	13
Alberta	46	44	1009	280	45
British Columbia	36	35	595	165	21
Total or Average	**296**	**285**	**793**	**220**	**226**

RECONSTRUCTION OF THE SPACE HEATING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET KPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Percent of total Heat loss
Newfoundland	5	0.4	653	-1152	-520	-1019	0.4	-0.6	19
Prince Edward Island	1	0.1	853	-1104	-498	-749	0.2	-0.2	14
Nova Scotia	8	0.9	879	-984	-444	-549	1.1	-0.7	12
New Brunswick	6	0.7	936	-1128	-509	-701	0.9	-0.7	13
Quebec	72	7.8	886	-1128	-509	-751	8.6	-7.3	14
Ontario	101	10.9	960	-984	-444	-468	14.9	-7.3	10
Manitoba	9	1.0	1017	-1416	-639	-1038	1.4	-1.5	16
Saskatchewan	12	1.3	1017	-1440	-649	-1072	1.9	-2.0	16
Alberta	46	4.9	960	-1344	-606	-990	6.8	-7.0	16
British Columbia	36	3.9	600	-792	-357	-549	3.3	-3.1	15
Total or Average	**296**	**31.9**	**894**	**-1090**	**-491**	**-687**	**39.5**	**-30.2**	**13**

SUMMARY

Gross Window Loss	-70 PJ	Net Window Performance	-30 PJ
Solar Contribution	40 PJ	Solar Fraction	15 %

NEW COMMERCIAL STOCK: 1989 - 2010

RECONSTRUCTION OF THE SPACE COOLING LOAD OF THE TOTAL COMMERCIAL STOCK

Province	Total Buildings (thousands)	Total Floor Area (Mega m2)	Space Cooling Index (MJ/m2 yr)	Space Cooling Index (kWh/m2 y)	Total Space Cooling (PJ)
Newfoundland	5	3.6	118	33	0.3
Prince Edward Island	1	1.3	126	35	0.1
Nova Scotia	8	8.1	133	37	0.7
New Brunswick	6	5.9	142	39	0.6
Quebec	72	69.3	150	42	7.2
Ontario	101	97.2	162	45	10.8
Manitoba	9	8.8	159	44	1.0
Saskatchewan	12	11.8	161	45	1.3
Alberta	46	44.2	164	45	5.0
British Columbia	36	34.8	147	41	3.5
Total or Average	**296**	**285.0**	**155**	**43**	**30.5**

RECONSTRUCTION OF THE SPACE COOLING LOAD ATTRIBUTABLE TO WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET KPI	Solar Load (PJ)	Total Window Gain (PJ)	Percent of total Cooling Load
Newfoundland	5	0.4	290	1.0	0.4	291	0.1	0.1	28
Prince Edward Island	1	0.1	308	2.2	1.0	311	0.0	0.0	28
Nova Scotia	8	0.9	326	3.5	1.6	331	0.2	0.2	28
New Brunswick	6	0.7	347	5.5	2.5	355	0.2	0.2	28
Quebec	72	7.8	367	7.5	3.4	378	2.0	2.0	28
Ontario	101	10.9	397	14.8	6.7	419	3.0	3.1	29
Manitoba	9	1.0	389	12.9	5.8	408	0.3	0.3	29
Saskatchewan	12	1.3	395	5.9	2.6	403	0.4	0.4	28
Alberta	46	4.9	400	5.9	2.6	409	1.4	1.4	28
British Columbia	36	3.9	359	5.7	2.6	368	1.0	1.0	28
Total or Average	**296**	**31.9**	**380**	**9.3**	**4.2**	**394**	**8.3**	**8.6**	**28**

SUMMARY

Summer Solar Gains	8 PJ
Total Window Cooling	9 PJ

NEW COMMERCIAL STOCK: 1989 - 2010

ULTIMATE POTENTIAL PERFORMANCE OF THE SOLAR APERTURE

GENERAL ASSUMPTIONS

Ultimate opening R-value	1.8	m2 C/W
Leakage Characteristic:CSA A-440	0.25	m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5	m/m2
Net leakage characteristic	0.112	m3/h m2 @ 5Pa
Solar transmittance	0.8	
Summer Shading Factor	0.8	
Mass effect: solar utilization	0.9	
Orientation factor	1.25	
Solar Gain/Random Incident	90	%

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Percent of Total Loss (%)
Newfoundland	5	0.4	979	-196	-13	770	0.6	0.4	1	33
Prince Edward Island	1	0.1	1280	-188	-12	1079	0.3	0.2	0	35
Nova Scotia	8	0.9	1319	-168	-11	1140	1.7	1.5	2	37
New Brunswick	6	0.7	1404	-192	-13	1199	1.3	1.1	2	36
Quebec	72	7.8	1328	-192	-13	1123	12.9	10.9	18	35
Ontario	101	10.9	1440	-168	-11	1261	22.4	19.6	27	37
Manitoba	9	1.0	1526	-241	-16	1268	2.1	1.8	3	35
Saskatchewan	12	1.3	1526	-245	-16	1264	2.9	2.4	4	35
Alberta	46	4.9	1440	-229	-15	1196	10.2	8.5	15	35
British Columbia	36	3.9	900	-135	-9	756	5.0	4.2	7	35
Total or Average	**296**	**31.9**	**1341**	**-186**	**-12**	**1143**	**59.3**	**50.6**	**81**	**36**

SUMMARY

Gross Window Loss	-9 PJ
Solar Contribution	59 PJ
Net Window Performance	51 PJ
Solar Fraction	21 %

CORRESPONDING COOLING PERFORMANCE OF WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET EPI	Solar Load (PJ)	Total Window Gain (PJ)	Conservation Potential (PJ)
Newfoundland	5	0.4	435	0.2	0.0	435	0.1	0.1	-0.0
Prince Edward Island	1	0.1	462	0.4	0.0	462	0.0	0.0	-0.0
Nova Scotia	8	0.9	489	0.6	0.0	489	0.3	0.3	-0.1
New Brunswick	6	0.7	520	0.9	0.1	521	0.2	0.2	-0.1
Quebec	72	7.8	551	1.3	0.1	553	2.9	2.9	-0.9
Ontario	101	10.9	596	2.5	0.2	598	4.5	4.5	-1.3
Manitoba	9	1.0	584	2.2	0.1	586	0.4	0.4	-0.1
Saskatchewan	12	1.3	592	1.0	0.1	593	0.5	0.5	-0.2
Alberta	46	4.9	601	1.0	0.1	602	2.0	2.0	-0.7
British Columbia	36	3.9	539	1.0	0.1	540	1.4	1.4	-0.5
Total or Average	**296**	**32**	**570**	**1.6**	**0.1**	**572**	**12.5**	**12.6**	**-3.9**

SUMMARY

Summer Solar Gains	13 PJ
Total Window Cooling	13 PJ

NEW COMMERCIAL STOCK: 1989 - 2010

REASONABLY ACHIEVABLE CONSERVATION POTENTIAL

GENERAL ASSUMPTIONS

Super Window R-value	0.8 m2 C/W
Leakage Characteristic	2.5 m3/h m of sash length @ 75 Pa
Sash length/area ratio	5.5 m/m2
Net leakage characteristic	1.120 m3/h m2 @ 5Pa
Solar transmittance	0.51
Summer Shading Factor	0.8
Mass effect: solar utilization	0.85
Orientation factor	1.10
Solar Gain/Random Incident	48 %

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE HEATING INDECES (MJ/m2 yr) Solar Gain	Conduction Loss	Air Change Loss	NET EPI	Solar Contribution (PJ)	Net Window Space Heat Gain (PJ)	Conservation Potential (PJ)	Conservatio Potential (%)
Newfoundland	5	0.4	519	-411	-130	-22	0.3	-0.0	0.6	18
Prince Edward Island	1	0.1	678	-394	-124	159	0.1	0.0	0.2	18
Nova Scotia	8	0.9	699	-351	-111	236	0.9	0.3	1.0	17
New Brunswick	6	0.7	744	-403	-127	214	0.7	0.2	0.9	17
Quebec	72	7.8	704	-403	-127	174	6.8	1.7	9.0	17
Ontario	101	10.9	763	-351	-111	301	11.8	4.7	11.9	17
Manitoba	9	1.0	808	-506	-160	143	1.1	0.2	1.7	18
Saskatchewan	12	1.3	808	-514	-162	132	1.5	0.2	2.3	18
Alberta	46	4.9	763	-480	-152	132	5.4	0.9	7.9	18
British Columbia	36	3.9	477	-283	-89	105	2.6	0.6	3.6	18
Total or Average	**296**	**31.9**	**710**	**-389**	**-123**	**199**	**31.4**	**8.8**	**39.0**	**17**

SUMMARY

Gross Window Loss	-23 PJ
Solar Contribution	31 PJ
Net Window Performance	9 PJ
Solar Fraction	12 %

CORRESPONDING COOLING PERFORMANCE OF WINDOWS

Province	Total Buildings (thousands)	Total Window Area (Mega m2)	SPACE COOLING INDECES (MJ/m2 yr) Solar	Conduction	Air Change	NET EPI	Solar Load (PJ)	Total Window Gain (PJ)	Conservation Potential (PJ)	Conservation Potential (PJ)
Newfoundland	5	0	230	0.3	0.1	231	0.1	0.1	0.02	21
Prince Edward Island	1	0	245	0.8	0.3	246	0.0	0.0	0.01	21
Nova Scotia	8	1	259	1.2	0.4	260	0.2	0.2	0.04	21
New Brunswick	6	1	275	2.0	0.6	278	0.1	0.1	0.03	22
Quebec	72	8	292	2.7	0.8	296	1.6	1.6	0.44	22
Ontario	101	11	316	5.3	1.7	323	2.4	2.4	0.72	23
Manitoba	9	1	309	4.6	1.5	315	0.2	0.2	0.06	23
Saskatchewan	12	1	314	2.1	0.7	317	0.3	0.3	0.08	22
Alberta	46	5	318	2.1	0.7	321	1.1	1.1	0.30	22
British Columbia	36	4	286	2.0	0.6	288	0.8	0.8	0.21	22
Total or Average	**296**	**32**	**302**	**3.3**	**1.1**	**307**	**6.6**	**6.7**	**1.92**	**22**

SUMMARY

Summer Solar Gains	7 PJ
Total Window Cooling	7 PJ

NEW COMMERCIAL STOCK: 1989 - 2010

MARKET PENETRATION SCENARIOS

Scenario "A": 10% market penetration

			CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
Province	Achievable Conservation Potential (PJ)	Market Penetration % -->	1	4	7	10
Newfoundland	0.6		0.01	0.02	0.04	0.06
Prince Edward Island	0.2		0.00	0.01	0.01	0.02
Nova Scotia	1.1		0.01	0.04	0.07	0.11
New Brunswick	0.9		0.01	0.04	0.06	0.09
Quebec	9.4		0.09	0.38	0.66	0.94
Ontario	12.6		0.13	0.51	0.89	1.26
Manitoba	1.7		0.02	0.07	0.12	0.17
Saskatchewan	2.3		0.02	0.09	0.16	0.23
Alberta	8.2		0.08	0.33	0.58	0.82
British Columbia	3.8		0.04	0.15	0.27	0.38
Total or Average	41		0.4	1.6	2.9	4.1

Scenario "B": 30% market penetration

			CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
Province	Achievable Conservation Potential (PJ)	Market Penetration % -->	3	12	21	30
Newfoundland	0.6		0.02	0.07	0.12	0.18
Prince Edward Island	0.2		0.01	0.02	0.04	0.06
Nova Scotia	1.1		0.03	0.13	0.22	0.32
New Brunswick	0.9		0.03	0.11	0.19	0.27
Quebec	9.4		0.28	1.13	1.98	2.82
Ontario	12.6		0.38	1.52	2.66	3.79
Manitoba	1.7		0.05	0.21	0.36	0.52
Saskatchewan	2.3		0.07	0.28	0.49	0.70
Alberta	8.2		0.25	0.99	1.73	2.47
British Columbia	3.8		0.12	0.46	0.81	1.15
Total or Average	41		1.2	4.9	8.6	12.3

Scenario "C": 70% market penetration

Province	Achievable Conservation Potential (PJ)		CUMULATIVE CONSERVATION (PJ)			
		Year -->	1995	2000	2005	2010
		Market Penetration % -->	7	28	49	70
Newfoundland	0.6		0.04	0.17	0.29	0.41
Prince Edward Island	0.2		0.01	0.05	0.10	0.14
Nova Scotia	1.1		0.07	0.30	0.52	0.74
New Brunswick	0.9		0.06	0.25	0.44	0.63
Quebec	9.4		0.66	2.63	4.61	6.59
Ontario	12.6		0.89	3.54	6.20	8.85
Manitoba	1.7		0.12	0.48	0.85	1.21
Saskatchewan	2.3		0.16	0.66	1.15	1.64
Alberta	8.2		0.58	2.30	4.03	5.76
British Columbia	3.8		0.27	1.08	1.88	2.69
Total or Average	41		2.9	11.5	20.1	28.7