RESEARCH REPORT

Residential Retrofit Potential in Canada

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RESIDENTIAL RETROFIT POTENTIAL IN CANADA

Residential Retrofit Potential in Canada

for the
Research Division
of
Canada Mortgage and Housing Corporation

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DISCLAIMER

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ABSTRACT

Energy efficiency upgrades can significantly reduce the environmental impact of housing. However, the extent of the upgrades required to have a meaningful impact the pollutant emissions of the residential sector has never been defined. While international agreements, such as the 1988 Toronto Protocol, provide target reductions for green house gases, the extent of the retrofit programs required within the residential sector to contribute to Canada's overall efforts to meet these goals was unknown. In order to provide direction to utility and government residential energy efficiency programs, Canada Mortgage and Housing Corporation conducted a study to determine the impacts of various levels of energy retrofits on the production of carbon dioxide by single detached housing stock in Canada. The levels of retrofit required to meet the intent the Toronto Protocol targets were also explored.

Several retrofit scenarios were proposed and applied to 765 actual house data files using a spreadsheet program that was developed to perform thermal simulations of base and upgraded houses, calculate amounts of pollutant emissions, perform retrofit costing, and calculate embodied energy and pollutants. Whole-house retrofits were performed including all portions of the envelope, mechanical systems, appliances and operation. An analysis was performed to ensure that the retrofit measures performed would not adversely affect indoor environment and durability.

The Toronto Protocol goal of achieving a 50% reduction in greenhouse gas emissions from **existing** Canadian housing was found to be technically feasible but will require a high level of retrofit. It should be noted that even higher levels of retrofit will be required to account for the anticipated growth in the housing stock to the year 2030.

KEY WORDS

Greenhouse Gases, Residential Retrofit, Energy Conservation, Environment

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1 EXECUTIVE SUMMARY

Reducing the production of green house gases attributable to residential energy use is critical for sustainable housing development. The targets of the 1988 Toronto Protocol serve as a useful measure by which the overall effectiveness of residential energy retrofit strategies can be assessed. The Protocol calls for green house gas emissions to be reduced to 80% of 1988 levels by 2005 and to 50% by the year 2030.

In order to evaluate the potential impact of residential energy retrofit strategies on greenhouse gas emissions, a research project was undertaken with the following objectives:

- To develop technically achievable retrofit strategies,
- To assess the energy efficiency impact of improved envelope performance, with an emphasis on wall retrofits,
- To assess the environmental impacts of the various retrofit strategies - both internally (indoor air quality) and externally (embodied energy and pollutants), and
- To assess the cost effectiveness of the retrofit strategies.

A range of retrofit designs were developed, primarily for wall sections, on the basis of their suitability for energy reduction, cost, embodied energy and pollutants, moisture buildup characteristics, and their effect on indoor air quality.

The retrofit process was applied to actual houses, using a subset of 765 single family dwellings from the CMHC STAtistically Representative (STAR) housing database, to evaluate the impact on energy consumed, indoor air quality and the environment.

An Excel-based spreadsheet program, Residential Energy & Economic Simulator (REES), was developed to carry out the following tasks in analyzing the retrofit process:

- thermal simulation,
- calculation of operating pollutants,
- costing, and
- calculation of embodied energy and pollutants.

The REES program was able to predict total energy use that averaged only 2% higher than measured for a random selection of 176 houses in the database

The results were extrapolated from the simulations, for individual houses, to the existing single-family Canadian housing stock, to determine overall determine overall possible energy and emission reductions, as well as retrofit costs. The housing stock was divided into five regions and six age categories.

Assuming the existence of a residential energy retrofit program running until the year 2030, the effect of residential retrofits on greenhouse gas (GHG) emissions was also determined. Allowances were made for the annual construction of new houses and demolition of old houses.

The retrofit potential of the housing stock was carried out under three intensities of retrofit effort: LOW, MID and HIGH. The MID and HIGH level retrofits included the addition of ventilation systems to compensate for anticipated reductions in natural air leakage due to sealing work. A description of the retrofit intensities and the calculated results follows:

- **HIGH Scenario** (approximately 30% higher than proposed National Energy Code for new House levels).

  Under the most intensive retrofit scenario studied, operating carbon dioxide emissions were reduced to 49% of 1989 levels. However, after factoring in new housing starts[1] and demolitions of existing housing, total equivalent GHG emissions were reduced to only 88% of 1988 levels by the year 2030,

- **MID Scenario** (bring all existing housing up to the proposed NECH).

  This scenario reduced operating carbon dioxide emissions to 61% of 1989 levels. However, after factoring in new housing starts and demolitions of existing housing, total equivalent GHG emissions were reduced to only 96% of 1988 levels by the year 2030.

- **LOW Scenario** (bring existing housing up to typical 1989 new house standards).

  The most modest retrofit scenario studied reduced operating carbon dioxide emissions to 75% of 1989 levels. However, after factoring in new housing starts and demolitions of existing housing, total equivalent GHG emissions were increased to 109% of 1988 levels by the year 2030.

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[1] New houses building codes, and the market place were assumed to result in houses that used about 2% per year less energy. By 2030, new houses would be using about 43% of those built in 1989 (approximately equal to current R-2000 levels of energy efficiency).

For all three scenarios, retrofits were performed on houses for which the effective cost[2] of source energy saved was less than $12 per GJ. This amounted to over 80% of the available housing stock.

All three retrofit scenarios included an "optimal indoor air quality" ventilation control that provided constant total air change during the heating season. Inside to outside temperature difference control (OTC) was simulated for a limited number of houses and was found to be nearly as effective as the optimal indoor air quality control strategy. Depending on the control setpoints, OTC ventilation resulted in from 4% less to 10% more energy use (and GHG generation) than the optimal strategy (but with total ventilation rates from 30% less to 20% more than that for the optimal control in some months).

Side yard zoning restrictions did not have a significant effect for the scenarios investigated, however, even with the HIGH scenario, there were only a limited number of "thick-wall" retrofits.

Embodied energy and embodied pollutants in the retrofits analyzed were generally repaid by reductions in operating energy and pollutants in less than one year.

Achieving a 50% reduction in carbon dioxide emissions from existing Canadian housing, while technically feasible, would be a massive undertaking requiring significant whole-house retrofits (i.e.; all portions of the envelope, mechanical systems, appliances and operation). Furthermore, extensive consumer education, builder training, and very likely tax/incentive programs would be required to support this effort. Alternative energy sources and new technologies that offer substantial increases in the energy efficiency of housing systems will need to be investigated and implemented to achieve these goals.

[2] This Effective Life-Cycle Energy Cost (ELCEC) was defined as the total energy-related retrofit cost divided by the present worth of energy saved (including embodied energy) - $12/GJ is about equal to the consumer price for electrical and oil heat.

RÉSUMÉ

Il est essentiel de réduire la production de gaz à effet de serre attribuable à la consommation d'énergie dans les habitations si l'on veut réaliser des aménagements résidentiels écologiques. Les objectifs fixés par la Conférence sur l'atmosphère en évolution de 1988 constituent des repères utiles à partir desquels il est possible d'évaluer l'efficacité globale des stratégies résidentielles de rattrapage éconergétique. Cette conférence visait à ramener, dès 2005, les émissions de gaz à effet de serre à 80 % de ce qu'elles étaient en 1988 et, en 2030, à 50 % des niveaux de 1988.

Pour évaluer l'incidence éventuelle des stratégies résidentielles de rattrapage éconergétique sur les émissions de gaz à effet de serre, on a entrepris une recherche qui avait pour objectifs :

- de mettre au point des stratégies de rattrapage éconergétique réalisables sur le plan technique;
- d'évaluer, du point de vue de l'efficacité énergétique, l'incidence de l'amélioration de la performance de l'enveloppe en mettant l'accent sur la rénovation des murs;
- d'évaluer les répercussions environnementales des diverses stratégies de rattrapage éconergétique, tant internes (qualité de l'air intérieur) qu'externes (polluants et énergie de production);
- d'évaluer l'efficience des stratégies de rattrapage éconergétique.

Diverses stratégies de rattrapage éconergétique ont été conçues, agissant principalement sur des sections de mur, en tenant compte de leur capacité à réduire la consommation d'énergie, des coûts, des polluants et de l'énergie de production, des caractéristiques en matière d'accumulation d'humidité et de leur effet sur la qualité de l'air intérieur.

Le processus de rattrapage a été appliqué à des maisons réelles en utilisant un sous-ensemble de 765 maisons individuelles issues de la base de données STAR-HOUSING de la SCHL afin d'en évaluer l'effet sur la consommation d'énergie, la qualité de l'air intérieur et l'environnement.

Une feuille de calcul, appelée *Residential Energy & Economic Simulator* (REES) [simulateur économique et énergétique pour les habitations], a été créée avec Excel pour exécuter les tâches suivantes dans l'analyse du processus de rattrapage éconergétique :

- simulation thermique;
- calcul des polluants d'exploitation;

- coûts;
- calcul des polluants et de l'énergie de production.

Le programme REES a été en mesure de prévoir la consommation totale d'énergie qui était en moyenne de 2 % supérieure seulement à celle mesurée pour un échantillon de 176 maisons choisies au hasard dans la base de données.

Les résultats ont été extrapolés à partir des simulations pour être appliqués au parc actuel de maisons individuelles du Canada afin de déterminer les réductions possibles de consommation d'énergie et d'émissions pour l'ensemble du parc ainsi que le coût des travaux de rattrapage. Le parc résidentiel a été divisé en cinq régions et en six groupes d'âges.

En admettant qu'un programme de rattrapage éconergétique pour les habitations soit mis sur pied et demeure en vigueur jusqu'en 2030, on a aussi déterminé l'effet qu'auraient des travaux de rattrapage résidentiels sur les émissions de gaz à effet de serre. On a tenu compte de la construction annuelle de nouvelles habitations et de la démolition des vieilles maisons.

Le potentiel de rattrapage du parc résidentiel a été examiné selon trois niveaux d'intensité : FAIBLE, MOYENNE et ÉLEVÉE. Les travaux d'intensité MOYENNE et ÉLEVÉE comportent la pose d'installations de ventilation pour compenser les réductions prévues des fuites d'air naturelles à la suite des travaux d'étanchéisation. On trouvera ci-dessous une description des niveaux d'intensité des travaux de rattrapage de même que le calcul des résultats :

- **Scénario INTENSITÉ ÉLEVÉE** (environ 30 % de mieux que ce qu'exigera le Code national de l'énergie pour les maisons neuves)

  Dans le cadre du scénario de rattrapage le plus intensif étudié, les émissions d'exploitation de dioxyde de carbone seraient réduites à 49 % des niveaux de 1989. Toutefois, lorsqu'on tient compte des mises en chantier[1] et des démolitions, les émissions équivalentes totales de gaz à effet de serre ne seraient réduites qu'à 88 % des niveaux de 1988 en 2030.

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1. On a supposé que les codes du bâtiment visant les maisons neuves ainsi que le marché donnaient des maisons qui consommaient environ 2 % moins d'énergie par année. En 2030, les maisons neuves consommeraient environ 43 % de ce que consommaient les maisons construites en 1989 (soit environ une consommation équivalente à celle des maisons R-2000 construites actuellement).

- **Scénario INTENSITÉ MOYENNE** (rénover toutes les maisons existantes de manière qu'elles respectent les exigences du Code national de l'énergie pour les habitations)

  Ce scénario permettrait de réduire les émissions d'exploitation de dioxyde de carbone à 61 % des niveaux de 1989. Cependant, lorsqu'on prend en considération les mises en chantier et les démolitions, les émissions équivalentes totales de gaz à effet de serre ne seraient réduites qu'à 96 % des niveaux de 1988 en 2030.

- **Scénario INTENSITÉ FAIBLE** (rénover les maisons existantes de manière qu'elles soient conformes aux normes des maisons construites en 1989)

  Le scénario de rattrapage le plus modeste étudié permettrait de réduire les émissions d'exploitation de dioxyde de carbone à 75 % des niveaux de 1989. Toutefois, quand on tient compte des mises en chantier et des démolitions, les émissions équivalentes totales de gaz à effet de serre augmenteraient en fait à 109 % des niveaux de 1988 en 2030.

Pour les trois scénarios, les travaux de rattrapage ont été appliqués à des maisons pour lesquelles le coût effectif[2] de l'énergie épargnée équivalait à moins de 12 $ par GJ, ce qui correspondait à plus de 80 % du parc résidentiel disponible.

Les trois scénarios de rattrapage incluaient une commande de ventilation permettant d'obtenir une qualité de l'air intérieur optimale ainsi qu'un renouvellement d'air total et constant durant la saison de chauffage. On a simulé le contrôle de la différence de température entre l'intérieur et l'extérieur pour quelques maisons et on a découvert que cette méthode était presque aussi efficace que la stratégie de qualité de l'air optimale. Selon les points de réglage déterminés, la ventilation fondée sur la différence de température a entraîné une consommation énergétique (et une production de gaz à effet de serre) variant entre 4 % de moins et 10 % de plus que la stratégie de qualité de l'air optimale (mais avec des taux de ventilation totale variant entre 30 % de moins et 20 % de plus que ce qui a été observé avec la stratégie de qualité de l'air optimale pour certains mois).

Les restrictions de zonage concernant la marge d'isolement latérale n'ont pas eu d'effets importants sur les scénarios étudiés. Or, même pour le scénario INTENSITÉ ÉLEVÉE, très peu de travaux de rattrapage visant à épaissir les murs ont été envisagés.

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2. Ce coût effectif de l'énergie du cycle de vie a été défini comme le coût énergétique total des travaux de rattrapage divisé par la valeur actuelle de l'énergie épargnée (incluant l'énergie de production) - 12 $/GJ correspond environ au prix que paie le consommateur pour le chauffage électrique ou au mazout.

Les polluants et l'énergie de production inhérents aux travaux de rattrapage analysés étaient généralement compensés en moins d'un an par les réductions d'énergie et de polluants d'exploitation réalisées.

Une réduction de 50 % des émissions de dioxyde de carbone produites par les habitations canadiennes actuelles, bien que techniquement possible, représenterait une opération massive qui nécessiterait d'importants travaux de rattrapage touchant des habitations entières (p. ex. toutes les parties de l'enveloppe, les installations mécaniques, les appareils et l'exploitation). En outre, il faudrait sensibiliser les consommateurs, former les constructeurs et fort probablement mettre sur pied des programmes fiscaux et incitatifs pour appuyer cet effort. Pour atteindre ces objectifs, il faudra rechercher et utiliser des sources d'énergie de rechange et des nouvelles technologies qui permettront de rendre beaucoup plus éconergétiques les composants des bâtiments.

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CONTENTS

2 BACKGROUND

Greenhouse gas emissions threaten to drastically alter the environment of the world. As the combustion of fossil fuels is directly related to the generation of greenhouse gases (esp. carbon dioxide which constitutes 90% of all energy-related greenhouse gas emissions), the implementation of energy efficiency measures represents an effective means of reducing the environmental impact of all sectors of the Canadian economy.

In 1994, the residential sector in Canada consumed about 1,392 PetaJoules (PJ) of secondary (i.e., end-use) energy per year which in turn produced about 40 megatonnes of carbon dioxide. This represents about 20% of Canada's total secondary energy use. Increases in fuel energy uses were, on average, 1.5% per annum from 1984 to 1994. Thus, the sizeable contributions of greenhouse gas emissions from the residential sector make it a worthwhile focus for energy efficiency measures.

Within the residential sector, energy efficiency measures can be applied to new and existing housing to reduce energy consumption associated with space conditioning, domestic hot water use, air exchange, lighting, appliances and lifestyles. As the number of houses within the existing housing stock greatly exceeds that expected to be built over the foreseeable future, the development and implementation of energy efficiency *retrofit* measures is critical to reduce the overall greenhouse gas emissions associated with housing.

It has been difficult to assess how intensively energy efficiency measures should be appled in order to have optimal effect The 1992 Framework Convention on Climate Change recommends the stabilization of greenhouse gas emission at 1990 levels by the year 2000. The 1988 Toronto Protocol sought to limit of future greenhouse gas (GHG) emissions to 80% of 1988 levels by the year 2005 and 50% of 1988 levels by 2030. In either case, the targets set by these international agreements can be used to assess how much energy use must be reduced in the residential sector. It is then a reasonably straightforward process to determine what retrofit measures, or packages of retrofit measures, must be applied to the housing stock to achieve the requisite energy use reductions.

In order to meet any targets for greenhouse gas emission reduction, energy consumption of new and existing housing would have to be reduced accordingly. The annual increase in the number of houses added to the housing stock by construction activity and the number of houses removed from the stock due to demolition must be considered.

It has been anticipated that environmentally sound and sustainable development of housing will require residential energy consumption to be cut drastically. Additionally, housing must be more durable to minimize resource use while providing a controlled, quality indoor environment. Improved thermal envelopes can improve all these aspects.

While energy efficiency retrofits reduce operating energy and associated pollutants, energy is required to produce the materials used in the retrofit and pollutants are generated in their production. These embodied energy and embodied pollutants must be determined to ensure that any retrofit program does not result in a net increase in energy use or pollutant generation over the period of implementation.

In older housing it is also difficult to assess the effect of retrofits on air-tightness, indoor air quality, thermal bridges and building durability. All of these factors require careful consideration prior to the implementation of an ambitious retrofit program to ensure that the residential retrofit program does not create occupant health or building structural problems.

3 OBJECTIVES

The project objectives were:

- to develop retrofit strategies to provide **technically achievable solutions**[3] to the goal of a 20% reduction in housing energy use by the year 2005 and a 50% reduction in housing energy use by the year 2030,
- to assess the energy efficiency impact of retrofit measures that provide improved envelope performance, with an emphasis on wall retrofits,
- to assess the environmental impacts of the various retrofit strategies - both internally (indoor air quality) and externally (embodied energy and pollutants),
- to assess the impact on durability of various retrofit strategies, and
- to assess the cost effectiveness of the retrofit strategies, with respect to existing fuel prices and projected environmental factors.

[3] Note that this was not a marketing study Market penetration rates of the various retrofits were assumed to be 100%

4 METHODOLOGY

Traditionally, housing archetypes ("typical houses") are used to determine the costs and benefits of conservation programs. While this approach is simpler than determining the costs and benefits of actual houses, it can only determine averages (energy, cost, etc.). The approach used here was to determine costs and benefits of retrofitting actual houses, in order to determine:

- which houses would be most cost-effective to retrofit,
- ventilation rates to provide adequate indoor air quality (and to not provide ventilation if it was not required),
- the range of retrofit costs and reductions to energy use and pollutant generation.

4.1 Database of Existing Houses

The CMHC STAR HOUSING (**STA**tistically **R**epresentative housing stock) database was obtained and HOT-2000[4] runs were performed using its 1,125 input files to create a single spreadsheet database[5]. The spreadsheet format made the data more readily accessible to the spreadsheet-based simulation program developed for this work (see section 4.3.1)

A statistical analysis of the STAR house database was carried out, in order to look for problem data. These quality control checks, and the use of only single-detached houses[6] reduced the usable database to 765 units. There continue to be problems with inconsistent or missing data. For example:

- furnace type information and quoted furnace efficiency often do not agree (the analysis therefore uses the furnace and water heater types in conjunction with a lookup table of known seasonal efficiencies),
- operating conditions (temperature, water use and base utilities) for newer houses use HOT-2000 default values (these houses are mostly from the CMHC/NRCan Merchant house air-tightness survey),
- some pre-1981 houses report basement temperatures of -2C. Only houses with basement temperatures greater than 10C were used, and

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[4] using HOT-2000 batch version 5.04

[5] The STAR database consists of 1,125 files - each representing one residential housing unit *"Environmental Impact Study: Phase I - Development of a Database on Housing Characteristics Representative of the Canadian Housing Stock"*, by Scanada Consultants Limited for CMHC, Research Division, 1992[1] - numbers in square brackets refer to References, section 7.

[6] The number of multi-family residential units were too few to break down into five regions and six age categories

- houses that had no, or conflicting, air-tightness information, used lookup values of NLA, based on province and age of the house.

4.2 Retrofit Options

The original objectives of this study were to assess the impact of wall retrofit options for Canadian houses, however it soon became apparent that the Toronto Protocol goal of a 50% reduction in carbon dioxide and other greenhouse gas emissions could only be achieved through whole house retrofits encompassing the entire building envelope, mechanical systems and operating conditions for a large portion of the existing housing stock.

The appropriate wall type was selected by the REES program - section 4.3.1, on the basis of several inputs:

- level of retrofit (LOW, MID or HIGH),
- region,
- space heating fuel, and
- constraints (Table 4.2, also discussed in Appendix F), such as regional factors: solid (no cavity) wall assumed in Ontario and Quebec if existing wall RSI was less than 1.2. Pre 1946 houses in Ontario were assumed[7] to have a brick exterior finish, so only interior retrofits were allowed.

Even with the range of wall types, it was not always possible to meet the goals for wall insulation. Since a reasonable level of retrofit was desired, a "threshold" for selection was assumed (Table 4.1). A threshold added RSI equal to zero would mean that retrofit would always be performed (fill cavities, for example). If the goal was to add RSI 0.1 to an insulated 2x4 wall of RSI 2.1 (NECH goal for gas heat in Vancouver is RSI 2.2, for example), then no retrofit would be performed, since the first option would be insulated sheathing with an RSI 0.5 threshold.

The wall retrofits that were developed as part of this study are listed in Table 4.1 (see Appendix A for graphic presentations), along with NLA reductions[8].

[7] The STAR database does not contain information on exterior finish.

[8] Factors based on *"Air Tightness, Before and after pressure tests demonstrate residential retrofit results"*, by Robert Dumont, SRC, from ASHRAE Journal, June 1984 [5] The paper is a summary of six whole house retrofit studies, showing increased air tightness of from 17% to 33% with air sealing retrofits (weatherstripping and caulking) to 70% with major wall and ceiling retrofits (including a new air/vapor barrier).

Table 4.1 Wall Retrofits

Wall Retrofit Type	Added RSI	Threshold[1] Added RSI	Remarks
1. Fill only -			
Fill wall cavity with insulation	1 4	0.0	low air sealing possible (reduce spread in NLA[2] 40%)
2. Exterior retrofit -			
Exterior insulated sheathing	1.1	0.5	moderate air sealing possible (reduce spread in NLA 75%)
Dynamic wall with exterior air diffuser	1 4	0 7	depressurized house draws air through the wall
Exterior curtain wall	4.4	2 6	poly wrap outside existing structure, then add site framed wall - very tight construction (reduce spread in NLA 95%)
Exterior wall truss	4 9	4.6	poly wrap outside existing structure, then add truss - very tight construction (reduce spread in NLA 95%)
3. Interior retrofit -			
Interior insulated sheathing	1 1	0 5	moderate air sealing possible (reduce spread in NLA 75%)
Dynamic wall with interior air diffuser	1 4	0 7	depressurized house draws air through the wall
Interior double wall	4 0	2.1	high air sealing possible; new vapor barrier (reduce spread in NLA 90%)

[1] The difference between the goal added RSI and existing RSI must be greater than the Threshold Added RSI in order for the wall retrofit type to be selected.

[2] NLA spread equals base house NLA minus minimum achievable NLA (taken as 75% of 1989 house for region)

Basement wall retrofits (diagrams in Appendix A) consisted entirely of interior framed walls, complete with gyproc, wiring and paint - resulting in a finished basement.

Over the rest of the envelope, the following retrofits were carried out - depending on the location, space heating fuel used and scenario (LOW, MID or HIGH):

- ceiling (attic assumed) - cellulose loose fill added,
- doors - replaced with steel insulated doors,
- windows - replaced with new units,
- heated crawlspaces - insulated in walls and on floors,
- unheated crawlspaces and overhanging floors - insulated in floor,
- basement floors and floor slabs - no retrofit,
- space heating systems replaced with more efficient units, including combined space and water heating systems,
- water heating systems replaced with more efficient units,
- air tightening[9]

[9] only whole-house retrofit packages were simulated, in part because field information on the effect of air tightening is only available for general, whole-house retrofits (see General Reference 6, section 7)

- ventilation systems added[10] (note that this **increases** energy use) to improve air quality in the tighter retrofitted houses. Several choices were made that effected the ventilation system efficiency[11] -
  - Ventilation fan efficiency could be specified to allow for the use of more efficient fans,
  - Outside temperature control (OTC) of ventilation fans; Specifiy inside to outside temperature difference below which fans operate,
  - Optimal fan control - operates fans to achieve specified (approximately 0.3) average monthly total air change rate (infiltration plus ventilation), and
  - Heat recovery added to reduce energy use (depending on level of retrofit),
- more efficient appliances and lights replacing existing units to reduce utilities[12] and outdoor energy use, and
- flow restrictors used to reduce hot water use.
- Main floor temperatures remained the same as for the base cases, however the basement temperatures increased when basement retrofits were carried out (due to effect of basement internal gains and increased occupancy of finished basement).

It was assumed that the energy-related portion of these retrofits would be performed as a consequence of opportunities provided by other renovation and retrofit activities. It was also assumed that the retrofit would not extend the envelope of the house (no rooms added to the existing house). Rooms could be built in upgraded basements, however.

A set of retrofit rules were developed (see Appendix F) in order to make the results more objective and repeatable, and to allow for automation of the retrofit calculations. Guiding specific selections within this framework of rules were several overall factors, that are summarized in Table 4.2.

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[10] Typically the capacity of the ventilation systems was 0.30 ac/h (as for NBC), but the fans did not necessarily operate continuously - depending on the ventilation control option selected by the user

[11] Control options for ventilation were: continuous fan (with or without summer operation), OTC (Outside Temperature Control) - ventilation fans operate only below a specified inside to outside temperature difference, and an optimal control that operated the fans so that the total of infiltration and ventilation equalled 0 3 air changes per hour during the heating season

[12] except where combustion space heating was used in hydro-electric dominated regions as a reduction in utilities under these circumstances would result in an increase in carbon dioxide emissions, due to the increased space heating requirements

Table 4.2 Retrofit Rules - General

Upgrade level scenario	upgrade level depending on scenario (LOW, MID, HIGH), province and space heating fuel type HIGH level scenario independantly adjustable with reference to MID scenario
Scenario **impact**	minimize cost or minimize environmental impact (program selects for certain options, such as basement fiberglass insulation to minimize cost or blown cellulose to minimize environmental impact)
Economic cutoff	Program selects not to perform retrofit if the life-cycle dollar per GJ equivalent cost of the retrofit is greater than a manually specified threshold.
Dynamic walls?	Yes or No
Strip finishes?	interior or exterior retrofit allowed or not
Attic type	ceilings assumed
Minimum wall upgrade	RSI 0.5, for example (to prevent upgrades that achieve very small changes)
Maximum wall upgrade (urban)	RSI 3.0, for example (to account for urban side yard restrictions)
Minimum window upgrade	RSI 0.10, for example (to prevent upgrades that achieve very small changes)
Mechanical systems upgrade?	Yes or NO (amount depending on scenario)
Reduce **hot water** consumption?	Yes or NO (amount depending on scenario)
Reduce **base load**?	Yes or NO (amount depending on scenario), no reduction for houses with combustion heating systems in regions with hydroelectric-dominated utilities (base load reductions would reduce energy use slightly, but would increase pollutant emissions)
Ventilation control	Continuous fan, OTC or optimal

During the simulation process, these retrofit rules were applied to each house in the database, in order to determine the best retrofit for that house, based on the existing envelope and mechanical system, climate, and fuel type, as well as available retrofit options.

4.2.1 Design

The design of an energy retrofit is a complex undertaking which involves drawing together and reconciling conflicting issues such as:

- the home's siting,
- the home's physical condition,
- the home's architecture,
- the home owner's priorities,
- the budget, and
- construction costs

Given the variability of the issues listed above it is not possible to provide a prescriptive approach that will provide an **optimal** solution for all cases.

A series of wall retrofit options are presented in Appendix A. They are based on the construction techniques presented in the builders manual produced in conjunction with this study.

When developing these wall retrofit options the following issues were addressed:

- applicability of the retrofit to the widest possible number of existing houses ,
- allow preservation of either interior or exterior finishes
- provide a range of insulation levels for use in different climates and different fuel cost regimes,
- structural considerations,
- allow easy use of enviromentally appropriate materials,
- minimization of moisture formation and accumulation inside the wall,
- connections to roofs, attics and ceilings (continuity of insulation and air barriers),
- cost of retrofit technique,
- energy savings,
- maximizing benefits (comfort, energy savings and building longevity and durability) for the cost of the retrofit.

4.2.2 Costing

Costing spreadsheets were developed for major categories of energy retrofit. Costing was broken out into eight main areas.

- Above grade walls,
- Attics,
- Doors,
- Windows,
- Exposed joist floors,
- Crawlspaces,
- Basement walls, and
- Mechanical systems

These components were then broken down by construction sequence and materials for pricing. The pricing information was based on R.S. Means Residential Cost Data for 1994 using a multiplier of 1.12 to adjust prices to those of Ontario which then forms the base pricing for the rest of Canada. Multipliers, derived for the NECH, were applied to the Ontario base costs to determine retrofit costs, based on the province in which the house was located. The spreadsheets were constructed to reference house component areas that are the normal area inputs for HOT-2000 (above grade walls, window, ceiling etc.). The following costing inputs were used in the spreadsheets.

- Materials costs,
- Installation costs (labour and equipment),
- Overhead and Profit, and
- Provincial tax and GST

The resulting outputs of the spreadsheets included the following:

- Energy-related and total cost[13] for the retrofit of the component (above grade wall, window, furnace, etc.).,
- Average cost per square meter of air sealing measures broken down by materials, installation, overhead and profit, and

Costs generated as part of the study were checked against local costing information supplied by construction materials suppliers, subcontractors (insulation installers, siding applicators), and general contractors.

The costs do not include demolition or disposal, but do include factors for waste.

4.2.3 Embodied Energy and Pollutants

The methods used to generate the embodied energy and pollutant generation values used in the analysis include:

- Research results of embodied properties (energy, pollutant generation) are considered to be most reliable and accurate if derived from physical or energy balance analyses of processes. Statistical analysis of industries using energy units are next in reliability and accuracy, and statistical analysis using dollar value energy conversions have the lowest reliability and accuracy. Therefore, where data was available from several sources, data from process analysis would take precedence over industry-wide statistical analysis (energy or cost based)
- Where accurate fuel mix figures are not available for Canada the gross energy figures from process studies have been proportioned by fuel types using the energy by fuel types for that industry from the 1990 Statistics Canada quarterly energy supply and demand figures.

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[13] Ceiling and crawlspace retrofit costs were assumed to be 100% energy related, however wall siding, basement framing and finishing were assumed to be non-energy related as they would be carried out as part of a normal residential retrofit. Energy related costs for windows, as well as space and water heating system upgrades were assumed to be the difference between the upgraded system and a replacement of the existing system (this differential will likely be reduced in the future as more efficient systems become common).

- Base industries are used in some cases and adjusted for variations in a product. For example, wood window frames are assumed to be the same as framing lumber with some additional waste and energy allowances for 100% kiln drying and added milling.
- Where process emissions figures are available for SOx, CO, NOx and VOC's and these clearly include energy emissions, emissions from energy use are not calculated. Aluminum electricity use is assumed to be all hydro and is exempted from emissions calculations[14].
- Process emissions are based on typical emissions controls for an "up to date" plant. This primarily affects particulate collection.
- Electricity calculations, for materials, are based on an average Canadian mix of 18% coal (at 33% overall efficiency), 60% hydro, 16% nuclear, 3% nat gas and 3% oil. Note that this assumption only applies to embodied properties, as regional electrical generation mixes are used for operating energy. Implicit in this assumption is that building materials and mechanical system components are transported to and from all parts of the country.

Some notes on the limitations of the analysis:

- Energy and emissions analysis typically includes extraction, transportation within the industry and processing to a deliverable building product.
- Where internal transport figures were not available and assumed to be very small they were disregarded.
- Transport to a building site, including transport of workers, were not included in the base properties tables, but were calculated separately on the basis of weight of product in the house retrofit.
- Small components of a product, such as a coating or sealer, were disregarded where data was poor and the component appears to make up less than 10% of the energy or emissions.
- Waste disposal of materials was not considered in the analysis (except for transport) and could result in some increase in emissions.
- Recycling of materials was not considered in the analysis and could result in a reduction in embodied energy and emissions.

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[14] Hydroelectric generation: Loss of carbon dioxide reduction due to flooding of forested areas, for new capacity, was not considered in this study

4.3 Retrofit Analysis

4.3.1 Residential Energy & Economic Simulator (REES)

The Residential Energy & Economic Simulator (REES) spreadsheet-based program was created to determine the costs and benefits of a variety of residential retofit programs. The program simultaneously calculates operating energy, at the house and at source, before and after retrofit, along with pollutant emissions - operational and embodied. Total and energy-related retrofit costs are also determined.

The thermal calculation "core" of the REES program is based on the algorithms of the HOT-2000 thermal simulation program (versions 5 through 7), including calculation of foundation losses and infiltration.

Input requirements are essentially those of HOT-2000, version 5 since this was the available output from the STAR database. Where additional data is required, such as for the AIM-2 infiltration model, it is either generated by the program or from lookup tables of defaults.

REES accesses the Excel spreadsheet database of 765 HOT-2000 outputs from the STAR house database. The control program steps through the house records sequentially (See organizational chart and details in Appendix B). A set of rules is used to determine the retrofits to be used for each house - depending on the envelope characteristics, mechanical systems, climate and fuel type.

Monthly simulations are performed on each house and the annual results for each house are copied, along with input documentation, into an output file in a format compatible with the input database. Two databases are created for each run - one for the base (unretrofitted) houses and a second database of retrofitted houses.

Results of the simulations for all the houses are extrapolated to the entire Canadian single-detached housing stock, by relating the results for the houses in five regions and six age categories with numbers of 1989 housing stock in each category.

The results are also extrapolated to the year 2030 by factoring in projections[15] for new housing starts, demolition rates and selected rates of retrofit implementation (Appendix C.2).

[15] projections for new housing starts and rates of demolition are based on historical regional values.

VALIDATION OF REES:

In order to check the REES calculation methodology:

- REES predicted space, water and total energy use were compared with measured energy consumption for 176 of the houses (note that a Degree Day compensation was required since the REES runs were using long term weather). The results of this analysis are presented in Section 5.3, and
- several comparison runs were performed with HOT-2000, version 7.1 (see Appendix D).

4.3.2 Moisture Analysis

In order to evaluate the wall retrofit options used in this study, from the point of view of durabilty, a moisture condensation analysis was performed. As insulation levels increase, parts of the wall that are outside the insulation become colder under winter conditions. Therefore it is essential to design and operate the walls as part of the building system so that condensation and/or freezing potential remain the same or are reduced.

Two computer programs were evaluated to determine their ability to determine condensation potential in wall retrofits:

- WALLFEM - a computer program that simulates the moisture and energy related performance of residential wall systems. The model is capable of simulating transient conditions in one, two or three dimensions.
- EMPTIED[16] - a simple MS-DOS computer program that estimates the potential amount of moisture that is likely to accumulate, month-by-month, in a specified building envelope through air leakage and vapour diffusion.

WALLFEM was not able to accurately model air leakage into walls, so EMPTIED was selected to carry out the condensation analysis.

Since the EMPTIED calculations are based on steady-state thermal and moisture equilibrium being attained during each incremental change in conditions, the results tend to reflect an upper limit, or worst case, for moisture deposition.

To calibrate the program, it was used to predict the moisture accumulation of several walls with known, field observed, moisture accumulation. These runs were then compared to results from retrofit

[16] EMPTIED: *"Envelope Moisture Performance Through Exfiltration and Diffusion"*, developed by Handegord and Company Inc. and Trow Consulting Engineers for CMHC[2]

wall sections, in order to ensure that the retrofitted walls would maintain, or enhance, the durability of the building envelope (equal or less moisture accumulation than walls known to not have moisture problems). The results of these simulations are presented in section 5.1.

4.3.3 Indoor Air Quality Analysis

An indoor air quality analysis was performed to ensure that the retrofits, in combination with air-tightening, and the ventilation system with its controls, maintained or enhanced existing indoor air quality when compared to existing houses and to health standards.

The indoor air quality model AQ1[17] was used for this analysis. AQ1 uses weather, pollutant and building characteristics to calculate hourly infiltration/ventilation rates and pollutant concentration rates in a one-zone building.

The AQ1 program uses the AIM-2 infiltration model to calculate natural infiltration (Walker and Wilson, 1990). Ventilation added by exhaust and supply fans is calculated using a fan model developed by Ecotope[18]. The program produces either hourly values or an annual summary of infiltration and pollutant concentration.

The following assumptions were made:

- whole house interior retrofits would result in pollutant source strengths similar to that for new houses, and
- pollutant source strengths for exterior retrofits would be equal or less than for interior retrofits.

AQ1 predicted pollutant concentrations for new houses, for which pollutant source strengths were known, were analysed[19] to determine air-tightness and ventilation requirement thresholds to avoid indoor air quality problems. These thresholds were used in the REES simulation rules to size the ventilation systems.

The results of this analysis are presented in section 5.2.

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[17] *"Indoor Air Quality Analysis for Detached Residences"*, by SAR engineering ltd et al for the Research Div. of CMHC, March 1992. [3]

[18] *"Field Measurement of Interaction of Mechanical System and Natural Infiltration"*, by L Palmiter, T. Bond, in the Proceedings of AIVC Conference, September 24-27, 1991, Vol. 1: Air Movement and Control in Buildings [4]

[19] *"Indoor Air Quality Analysis for Detached Residences"*, by SAR engineeing ltd eta al for the Research Div. of CMHC, March 1992 [3]

4.4 Projections to Canadian Housing Stock

The REES program includes a set of spreadsheets that project the results of each set of simulations to the existing single detached housing stock. The Canadian housing stock (Statistics Canada, 1989) was classified into five regions and six age categories.

The Canadian housing stock information from Statistics Canada was analysed to indicate directions in which a retrofit program could proceed, and to assist in developing the retrofit rules (see Retrofit Options, section 4.2, and Appendix F) for the REES program. This analysis showed several interesting trends:

- Pre 1981 housing (15+ years old) - amount to 84% of the total housing stock (older houses are more likely to be retrofitted with new siding, new interior finishes, etc.),
- Single-detached housing amounts to 78% of the total (single-detached, semi-detached and row housing), and
- Pre 1945, rural single-detached housing amounts to over 854,000 units - outnumbering the under 500,000 pre 1945 urban single detached units. This fact is significant as rural housing is less likely to be restricted by regulations governing side yard property line set back requirements, for example, that could curtail curtain or truss-wall external retrofits. These houses therefore represent a target market for high level retrofits.

While an analysis on a provincial basis was originally planned and would be desirable, the STAR housing data for some east coast and prairie provinces is not representative in some age categories, so the following provinces/regions were used for purposes of grouping the database into more meaningful regional classifications:

- B.C.,
- Prairies (Alberta, Saskatchewan, Manitoba),
- Ontario,
- Quebec, and the
- Maritimes (Newfoundland, Nova Scotia, P.E.I., New Brunswick)

Since the STAR house database consists of about 90% single-detached units, the remaining 10% of semi-detached and row units, when spread across five regions and six age categories, would not result in statistically valid results. Therefore the simulations and costing were carried out for **single-detached units only**.

The confidence that can be placed in such a projection is a function of the representativeness of a sample of houses with respect to the general housing stock. The representativeness of a sample depends on the sampling method and on the size of the sample. Sampling methods were addressed in the Scanada report describing the setting up of the STAR database.

Sample sizes, and their relationship to the housing stock are shown in Figure 4.1. Across Canada, the ratio of housing stock to single detached houses used in the analysis was 8,463. Generally, pre-1945 houses are under-sampled, with an average ratio of 14,822 housing stock to database houses for pre-1921 and 9,372 for 1921 to 1945 houses. These older houses in Ontario, Quebec and the Maritimes, in particular, require larger sample sizes (the Maritimes had only 3 houses in each of these two age categories).

The approach used to extrapolate the simulation results to the Canadian housing stock was to determine energy and pollutant reduction associated with retrofitting specific houses in the database. The averages of energy and pollutant reduction by region and age were then determined for the houses in the two output databases created by the REES run (section 4.3.1) - the base (unretrofitted) database and the upgrade (retrofitted) database. Differences in energy and pollutant generation were determined by region and age category. Energy upgrade related and total retrofit costs were also determined.

In order to improve the confidence in the results, statistical analyses of the base and upgrade databases were also performed to determine:

- space heating breakdown by fuel type, to ensure that the number of houses in each category were representative of the total housing stock,
- number of houses retrofitted, as well as the ratio of housing stock to retrofitted houses, in each region and age category, to ensure that the number of database houses in each category was large enough to be representative,
- the range distribution of heating season air change rates to ensure that the modelling was producing realistic results, and
- ratio of retrofit costs to life-cycle net energy savings (the latter taken to be equal to annual energy savings times a present worth factor[20], minus the total embodied energy associated with the retrofit), to ensure that costs and predicted energy savings were within reasonable

[20] This is a conservative approach, since it assumes that future energy savings are not "worth" as much as present costs The result is a dollar per GJ value that can be compared to fuel prices. The analysis used a 30 year life cycle analysis with a Present Worth Factor, or PWF of 18 (achievable with a 6% discount rate and just over 2% real energy escalation rate - or other similar combinations).

bounds (note that this ratio was also used in some runs as an economic "cutoff" to determine if a retrofit should be performed).

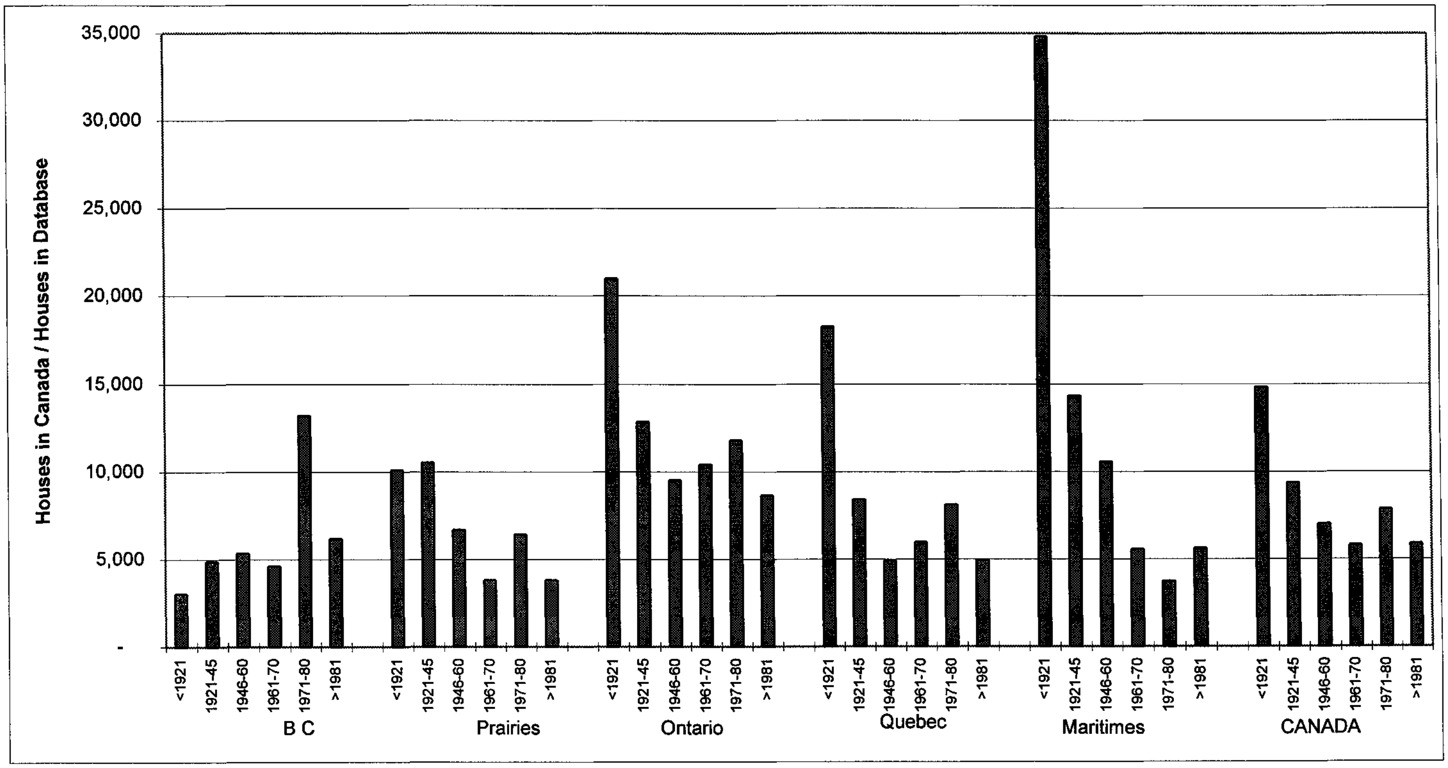
Housing Projections to the year 2030

The results of some retrofit scenarios were also incorporated into a time projection, that incorporated projections of total single detached housing stock, new housing starts, demolition rates and retrofit rates through to the year 2030.

In order to determine energy use and pollutant generation for new houses, it was assumed that they would be equivalent to the 1989 base (unretrofitted) houses for each region. To account for changes in new housing codes, the energy use and pollutant generation for these houses was modified over time with "efficiency improvement" factors. Embodied energy and emissions associated with the operation of the new houses was determined, however embodied energy and pollutants associated with the construction of the new houses was not determined. As the focus of this study was the retrofitting of existing houses, more effort should be put into the analysis of new house trends, including projected housing starts, increases in efficiency, embodied energy and pollutants associated with construction, and the use of recyled materials.

The retrofit analyses in this study use 1989 as a reference (based on detailed Statistics Canada housing stock figures for 1989). Overall energy use and greenhouse gas generation for 1989 were extrapolated back to 1988 - the base year for the Toronto Protocols.

Figure 4.1 Canadian Housing Stock



Single Detached Houses:

Const Date	B.C.		Prairies		Ontario		Quebec		Maritimes		Canada	
	in DB (#)	Housing Stock	in DB (#)	Housing Stock	in DB (#)	Housing Stock	in DB (#)	Housing Stock	in DB (#)	Housing Stock	in DB (#)	Housing Stock
<1921	10	30,145	11	110,948	14	293,520	7	127,881	3	104,486	45	666,980
1921-45	22	107,100	16	168,504	19	244,171	11	92,711	5	71,687	73	684,173
1946-60	35	186,710	44	294,130	55	523,527	48	235,390	11	116,284	193	1,356,041
1961-70	29	133,505	49	186,788	28	291,760	31	185,087	14	77,904	151	875,044
1971-80	16	211,649	43	275,851	27	318,531	28	227,748	33	123,055	147	1,156,834
>1981	21	129,924	40	152,463	42	364,300	38	188,034	15	84,329	156	919,050
TOTAL	133	799,033	203	1,188,684	185	2,035,809	163	1,056,851	81	577,745	765	5,658,122
Average	22		34		31		27		14			

Note: in DB (#) = number of houses in database
Housing Stock = Single-detached houses in region and age category (Statistics Canada, 1989)

5 RESULTS

5.1 Condensation Issues

The CMHC EMPTIED program was used to predict the moisture accumulation potential of several walls with known, field observed[21], performance, as well as walls used in this study. The following rationale was used.

The 2x4 and 2x6 walls represent current practice and they do not result in condensation problems under normal winter conditions. Table 5.1 allows us to compare several upgrade scenarios, so that we can relate the condensation performance of the wall upgrades to current practice. Unshaded areas are "safe", while shaded areas represent conditions of increased condensation potential.

Table 5.1 Predicted Condensation in Walls (location: Regina, SA)

Relative humidity profile[1]		Normal	Normal	Normal	Normal	High	High
	NLA (cm2/m2)	2x4	2x6	2x4, sheathed inside	2x4, ext. truss wall	2x4, strapped inside	2x4, ext. truss wall
Vapor barrier location (% from inside)		0%	0%	30%	33%	30%	33%
Condensation (absorbed & drained)		(kg/m^2)	(kg/m^2)	(kg/m^2)	(kg/m^2)	(kg/m^2)	(kg/m^2)
Variations in Normalized Leakage	0 7	14	14	14	15	20	20
Area (NLA)	2 0	21	20	21	23	35	36
	4 0	**31**	**29**	31	34	58	60
	6 0	41	39	41	46	80	85

[1] 'Normal' is a profile with average monthly winter relative humidities from 36% in October, down to 22% in January, up to 34% in April; 'High' has winter relative humidities held constant at 40%

For example, with a conventional 2x4 wall with an NLA of 4.0 cm^2/m^2, under normal winter conditions, EMPTIED predicts 31 kg/m^2 of condensation. Since this wall is known to have no significant problems with condensation, the sheathed 2x4 wall and the 2x4 with exterior truss wall will likely also not have condensation problems either, as long as their NLA values are significantly less than the original wall.

Since the air tightening assumed in this study was linked to the type of wall, NLA values were automatically reduced according to the type of wall retrofit. Sheathed walls, for example, were associated with air-tightening that resulted in an NLA of typically less than 2.0 cm^2/m^2. An NLA of 2.0 cm^2/m^2, in the example above, would have resulted in a predicted condensation of 21 kg/m^2 under normal conditions - less than the original wall. The 2x4 with exterior truss wall had only slightly

[21] personal communication from Dr. Robert Dumont, SRC, based on field test huts in Saskatchewan Under normal winter operating conditions, walls with vapor barriers located up 33% of the depth of the wall from the inside surface suffered no condensation effects.

higher value of 23 kg/m^2 under normal operating conditions, but NLA values were typically reduced even more with this type of retrofit.

High winter relative humidities are unlikely with the retrofitted houses since their ventilation systems would reduce levels of humidity.

Therefore, although the retrofits generally increase the risk of condensation[22] by increasing the amount of insulation (colder sheathing) and some also move the vapor barrier into the wall (colder vapor barrier), they significantly reduce condensation risk by sealing paths of air movement into the wall, and provide ventilation to reduce high humidity levels.

Until further field studies can confirm safe operation at higher levels of predicted condensation, care must be taken to ensure that all retrofit options resulting in colder vapor barrier or sheathing incorporate adequate air tightening and controlled ventilation.

5.2 Indoor Air Quality Issues

Any program promoting interior retrofits should include guidelines, standards and training in the use of materials with low emissions of toxic, mutagenic and carcinogenic pollutants. In addition, because of the probability of some pollutant generating materials being present in any house, some form of ventilation will be required in all, or at least in the more air-tight houses proposed under a full retrofit program.

To promote air circulation, it was assumed that, where applicable, forced air circulation fans operated continuously. This and the ventilation requirements, discussed below, both increased electrical energy use compared to the base houses, most of which had furnace fans operating intermittently and no ventilation systems.

The ventilation requirements for new housing under the National Building Code (1995) were used for this study. Ventilation was therefore based on an attempt to achieve a total infiltration plus ventilation of about 0.3 air changes per hour[23].

The REES program calculated natural air change rates in the "shoulder seasons" (April and October) in order to determine the forced ventilation requirement to achieve a total of 0.3 air changes per hour. With continuous ventilation systems, the **capacity** of forced ventilation was doubled to allow for increased ventilation during peak demands.

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[22] Exterior insulated sheathing is an exception, since it not only improves the air-tightness, but also results in a warmer existing wall - thereby reducing the risk of condensation further.

[23] Simulations using the AQ1 indoor air quality model also indicated 0 3 average air changes per hour resulted in reasonable indoor air quality with typical interior construction With proper selection of materials, pollutant concentrations would be reduced further.

Various control scenarios were then implemented to maintain adequate air quality while minimizing energy use. In order to show the maximum technically achievable reductions in energy and greenhouse gases, while maintaining indoor air quality, most runs were performed with a ventilation control that operated the fans so that the total average air change of about 0.3 air changes per hour was maintained for all months of the heating season (optimal control). This would result in a nearly constant state of indoor air quality.

One type that approximates the optimum is an inside to outside temperature difference (OTC) ventilation controller. OTC activates the ventilation system when the temperature difference is too small to provide adequate air change through infiltration (typically during the spring and fall). The REES program can simulate an OTC as long as the user specifies the temperature difference (inside to outside) above which the fans will be turned on.

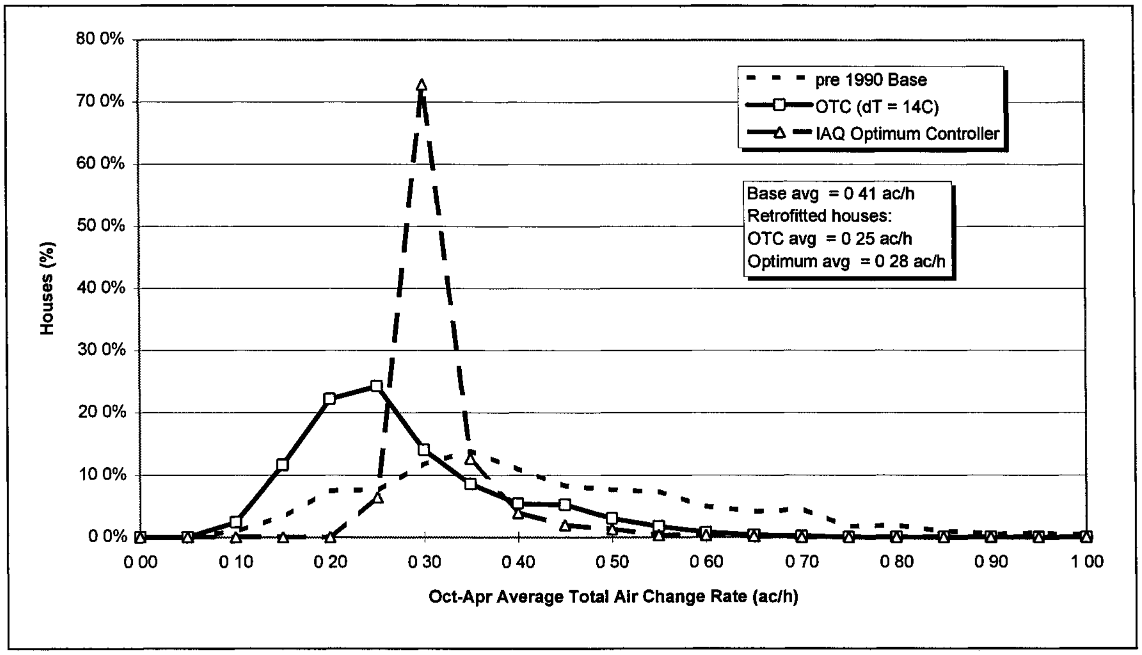
A series of OTC runs on individual houses found that this type of controller could closely approximate an optimal controller, however, the optimal temperature difference setpoint was highly dependant on:

- air-tightness of the house, and
- climate

The detailed results in Appendix E show that adequate ventilation in the critical spring and fall months can be achieved with a very small energy penalty. In all cases, the OTC runs resulted in operating carbon dioxide generation and space heat fuel use that was within -3% to +10% of the optimum (iaq_opt). Selecting the control temperature such that OTC resulted in the same average total ventilation as the optimal controller, usually had the lowest LCEC - indicating the most economic option, however minimum monthly total air change dropped to as low as 0.16 ac/h in some cases. These houses were sufficiently air-tight that the natural infiltration during cold months (fan off) was inadequate to maintain good air quality. A control that provides a constant minimum ventilation plus OTC may be necessary to avoid too low ventilation in tight houses.

Runs with a single setpoint result in a too much scatter - with some houses having too much ventilation and some too little (see Figure 5.1). The results for the "optimal" controller (as implemented in REES) show very little scatter around the 0.30 ac/h goal, while the OTC results for a 14C setpoint result in air change rates from 0.10 ac/h to 0.70 ac/h.

Figure 5.1 Ventilation controls



The analysis of seven houses in Appendix E used optimal inside to outside temperature difference setpoints ranging from 11C (loose house in B.C.), to 46C (tight house in Manitoba). Until "smart" algorithms can be developed that enable the program to determine the optimal OTC setpoint for each house, REES can be used for manual OTC runs, where the user selects the setpoint.

The indoor air quality critical retrofits are likely to be those involving extensive interior work - with pollutant source strengths approaching that of new house construction. Table 5.2 shows that, for these houses, optimal ventilation control resulted in no houses with winter total infiltration plus ventilation rates averaging less than 0.25 air changes per hour.

Table 5.2 Effect of Ventilation Control on Heating Season Average Air Change Rate (Optimal control vs Continuous fans)

				Optimal (H12C01)			Continuous (H12C02)		
		Base houses	Interior retrofits	All houses	All houses	Interior retrofits	All houses	All houses	Interior retrofits
		Ventilation + Infiltration	fraction	Ventilation + Infiltration	Vent.+ Infil. more than	Vent.+ Infil. less than	Ventilation + Infiltration	Vent.+ Infil more than	Vent.+ Infil less than
Period	Region	ac/h	%	ac/h	0 40 ac/h	0 25 ac/h	ac/h	0.40 ac/h	0 25 ac/h
<1921	BC	0 70	0%	0.34	10%	0%	0.48	90%	0%
1921-45	BC	0 60	0%	0.33	5%	0%	0 47	50%	0%
1946-60	BC	0 53	0%	0 35	9%	0%	0.51	49%	0%
1961-70	BC	0 44	0%	0.31	3%	0%	0 43	41%	0%
1971-80	BC	0.39	0%	0.33	6%	0%	0 47	31%	0%
>1981	BC	0 21	0%	0.25	0%	0%	0 35	5%	0%
<1921	PR	0 54	9%	0.29	0%	0%	0.40	36%	0%
1921-45	PR	0 47	13%	0 28	0%	0%	0.39	31%	0%
1946-60	PR	0 31	7%	0 28	2%	0%	0.38	16%	0%
1961-70	PR	0 27	8%	0 26	0%	0%	0 37	10%	0%
1971-80	PR	0 20	5%	0 27	0%	0%	0 36	7%	0%
>1981	PR	0 22	0%	0.26	0%	0%	0 35	3%	0%
<1921	ON	0 78	100%	0 40	50%	0%	0.56	100%	0%
1921-45	ON	0 61	100%	0 34	5%	0%	0.48	95%	0%
1946-60	ON	0 37	0%	0.28	2%	0%	0.40	25%	0%
1961-70	ON	0 33	0%	0 27	0%	0%	0.39	14%	0%
1971-80	ON	0 28	4%	0 27	0%	0%	0 38	4%	0%
>1981	ON	0 19	0%	0.26	0%	0%	0 36	7%	0%
<1921	QU	0 60	14%	0 28	0%	0%	0 40	29%	0%
1921-45	QU	0 54	18%	0.29	9%	0%	0 40	18%	0%
1946-60	QU	0 40	33%	0.28	4%	0%	0 39	27%	0%
1961-70	QU	0 32	23%	0 27	0%	0%	0.38	13%	0%
1971-80	QU	0 28	14%	0 27	0%	0%	0.38	4%	0%
>1981	QU	0 15	0%	0 27	0%	0%	0.37	0%	0%
<1921	MT	0 79	0%	0 36	33%	0%	0.51	100%	0%
1921-45	MT	0 89	0%	0.36	40%	0%	0.50	80%	0%
1946-60	MT	0 60	27%	0 31	18%	0%	0.44	73%	0%
1961-70	MT	0 49	57%	0 30	0%	0%	0 42	57%	0%
1971-80	MT	0 37	9%	0 27	0%	0%	0.38	12%	0%
>1981	MT	0 17	0%	0 25	0%	0%	0.34	0%	0%

Compared to a 0.3 ac/h goal, the older base (unretrofitted) houses were generally over ventilated due to leaky construction, while newer base houses were often under-ventilated due to tighter construction (very few had forced ventilation).

Both optimal and continuous fans were able to maintain all interior retrofits at greater than 0.25 ac/h (designed to provide 0.30 ac/h in April and October), however continuous fans resulted in over-ventilation (greater than 0.40 ac/h) of a significant fraction of the houses. Most older retrofitted houses are not sufficiently air-tight to require continuous ventilation. This should be confirmed by field observations, however.

5.3 Comparison of Operating Energy

A comparison of REES-predicted energy use with measured values[1] was carried out for a random selection of 176 houses in the database (23% of the total). The measured data were obtained by split-metering and provide values for total space heating, water heating and utilities (including outdoor energy use). In addition, Degree Days (base 18C) were available for the monitored period for each house.

Based on the average energy requirements of the 176 house sample, REES predicted space heating 2% higher than that measured,[24] water heating 3% higher than measured, and total energy use 2% higher than measured. HOT-2000 version 5, previously used by Scanada [1], predicted total energy use 5% less than measured[25] for the same houses.

Uncertainties in average furnace and water heater efficiencies, as well as unknowns in the operating conditions, could easily account for these differences. The predictions are sufficiently close to real energy use that predicted retrofit savings should be quite reliable[26]. Predicted savings should be compared with field measured savings from retrofitted houses when they become available, however.

5.4 Energy and Environmental Impacts

REES simulations were performed, using several retrofit scenarios, including variations on the following:

- **HIGH** scenario: Levels of envelope performance approximately 30% greater than that proposed in version 2 of the National Energy Code for Houses (NECH)[27],
- **MID** scenario: equal to NECH version 2, and
- **LOW** scenario: levels of envelope and mechanical system performance equal to typical 1989 housing for the region.

Most of the base houses had uninsulated basements - usually with temperatures indicated to be in the 14C to 18C range. The houses with

[24] The REES space heating results used long-term average weather, so the predictions were corrected by the ratio of actual Degree Days to long term Degree Days (long term Degree Days averaged 4% lower than actual) The correction increased the REES values by an average of 5%.

[25] Note that version 7 of HOT-2000 predicts space heating energy use about 10% to 15% higher than version 5.

[26] REES predicted retrofit upgrade energy savings of 5% less than predicted by version 7 of HOT-2000 for a sample of 3 houses (Appendix D).

[27] The level of retrofit was linked to the NECH because it has a basis in life-cycle costed economic levels of thermal performance (for **new** houses, however) It would also be politically easier to implement levels of insulation in a retrofit program if they are equal, or at least linked, to new house levels. *"National Energy Code for Houses, 1995 ver 2 0"*, Canadian Commission on Building and Fire Codes, 23 March, 1995 [6]

retrofitted (insulated) basements, were assumed to have basement temperatures 2C lower than the main floor temperatures[28]. This usually meant an **increase in basement temperature** of from 1C to 3C - **somewhat reducing the energy savings associated with the basement retrofit**.

The simulations were carried out using average weather for the city in which the house was located, or a nearby alternate if weather data was not available.

The values shown in the following tables are for **source** carbon dioxide and energy reduction[29] - including the generation and transmission losses for electrical generation[30].

The REES program calculates quantity takeoffs for each house, in order to determine amounts of each material used in the retrofit, along with its associated energy and pollutants. Energy and pollutants associated with the retrofit were generally found to be paid back in less than one year (see Table 5.4c and Appendix C).

Figures 5.2 and 5.3 illustrate the effect of retrofitting only the more cost effective cases. In Figure 5.2, all 765 houses were retrofitted to HIGH levels (run H99C01). The lines on the graph represent constant energy-related retrofit cost divided by life-cycle net energy saved - a Life Cycle Energy Cost (LCEC). The life-cycle net energy is equal to the life-time (30 years in this case) energy[31] savings for electric utilities, water heating and space heating minus the embodied energy expended to carry out the retrofit. The units are \$/GJ (dollars spent per GJ saved) - an energy cost, except that the source of the energy is conservation.

$$LCEC = \frac{(RetrofitCost)}{(Life \times Energy_{saved/year} - Energy_{embodied})} \quad ,\$/GJ$$

Assuming that future energy savings are not as valuable - not "worth" as much as energy purchased today, future energy savings must be discounted back to the present. Therefore, instead of multiplying operating energy savings by the life-time of 30 years, a "Present Worth Factor", or PWF was used. The PWF accounts for typical real energy

[28] The effect of internal sources of heat (furnace, water tank, ducts, etc.) after insulating the basement would result in an increase in temperature. In addition, the insulated and finished basement would more likely be occupied (and therefore heated).

[29] Note that the source energy is used for combustion fuels only - not for nuclear or hydroelectric, as the the former has no impact on greenhouse gas generation and the impact of hydroelectric (methane generation due to rotting of flooded valleys) is unknown. Further research would be required if the thermal and greenhouse gas effects of these electrical generation sources are to be included

[30] Electrical generation split for 1989 (Scanada STAR housing database report [1]), also see section 4 3

[31] Because this is a "societal" analysis, source energy was used for both the operating savings and the embodied energy. Electrical generation and transmission inefficiencies were therefore factored into the analysis.

inflation rates, value of money invested, etc.. This analysis used a PWF equal to 18[32] - resulting in an "Effective Life Cycle Energy Cost", or ELCEC[33].

$$ELCEC = \frac{(RetrofitCost)}{(PWF \times Energy_{saved/year} - Energy_{embodied})} \quad ,\$/GJ$$

In Figure 5.3 only houses with an Effective Life Cycle Energy Cost (ELCEC) less than $12/GJ were retrofitted (run H12C01) - amounting to 81% of the available housing stock. The $12/GJ threshold was used as it represents approximately the consumer cost of electric and oil heating, and is probably close to the consumer cost of gas heating if a greenhouse gas driven "environmental factor" were included[34].

Note that, in Figure 5.3), the houses to the left of the $12/GJ ELCEC line (in Figure 5.2) were not retrofitted, due to being "uneconomic", based on the $12/GJ retrofit criteria.

Since most of the non-retrofitted houses had relatively low net energy savings[35], dropping them from a retrofit program has a small impact on overall energy and emissions reductions - a HIGH level retrofit of all the houses (run H99C01) reduced operating carbon dioxide emissions to 46% of original levels, while carrying out retrofits on 81% of the houses meeting the maximum ELCEC criteria of $12/GJ, reduced carbon dioxide emissions to 49% (run ID H12C01, see Table 5.7).

This analysis shows a benefit of analysing a database of real houses instead of a few average archetypes - "outliers" with poor retrofit cost to energy savings ratios can be eliminated from the analysis.

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[32] A PWF equal to 18 corresponds to a 6% discount rate and a real energy inflation rate of 2.2% per year.

[33] While the ELCEC is economically "correct" in that it assumes future savings are not worth as much as today's costs, this type of analysis fails to account for future environmental costs such as global warming due to emissions of greenhouse gases Therefore the LCEC may be a truer representation of societal factors - in effect incorporating a higher "energy inflation factor" to account for environmental costs in order to obtain a PWF equal to 30 (obtainable with a 6% discount rate and a real energy inflation rate of 6% - or an immediate increase in the environmental value of energy followed by an energy inflation rate less than 6%)

[34] Assigning values to GHG driven "environmental factors" for the different types of heating fuels is an area requiring further research, but was beyond the scope of this study

[35] life-cycle net energy is equal to the life-time (30 years in this case) energy savings for electric utilities, water heating and space heating minus the embodied energy expended to carry out the retrofit

Figure 5.2 Residential Retrofit Cost vs Life-Cycle Energy Saved (765 houses retrofitted)

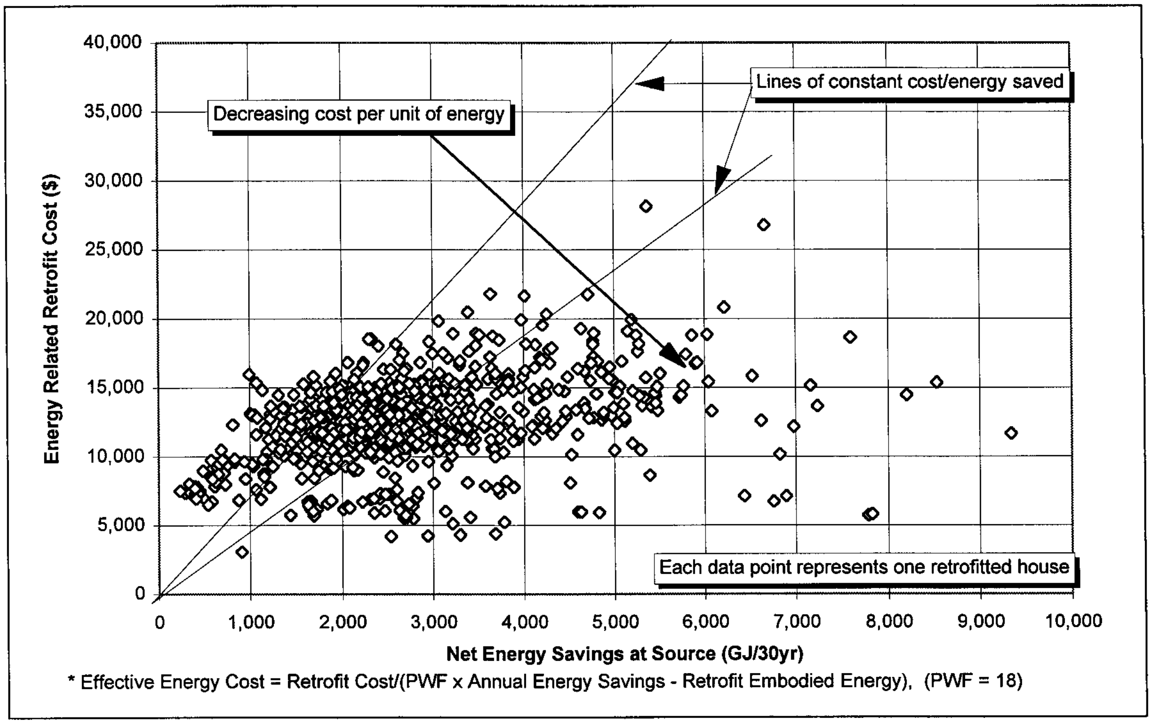
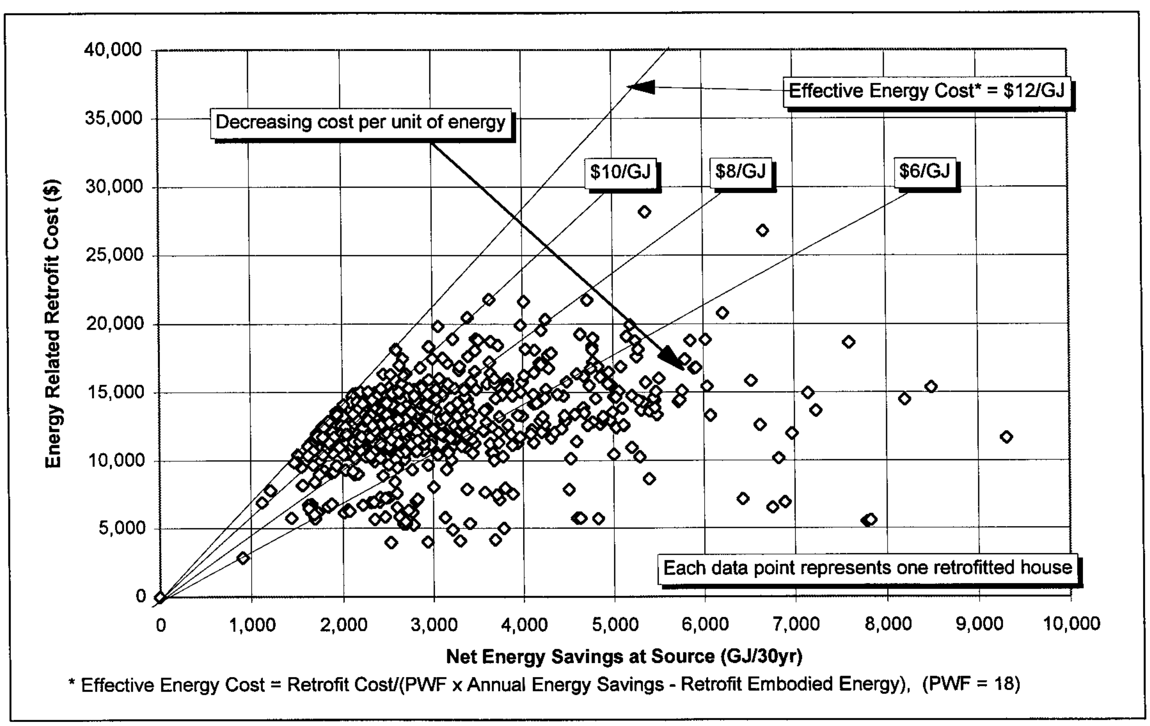


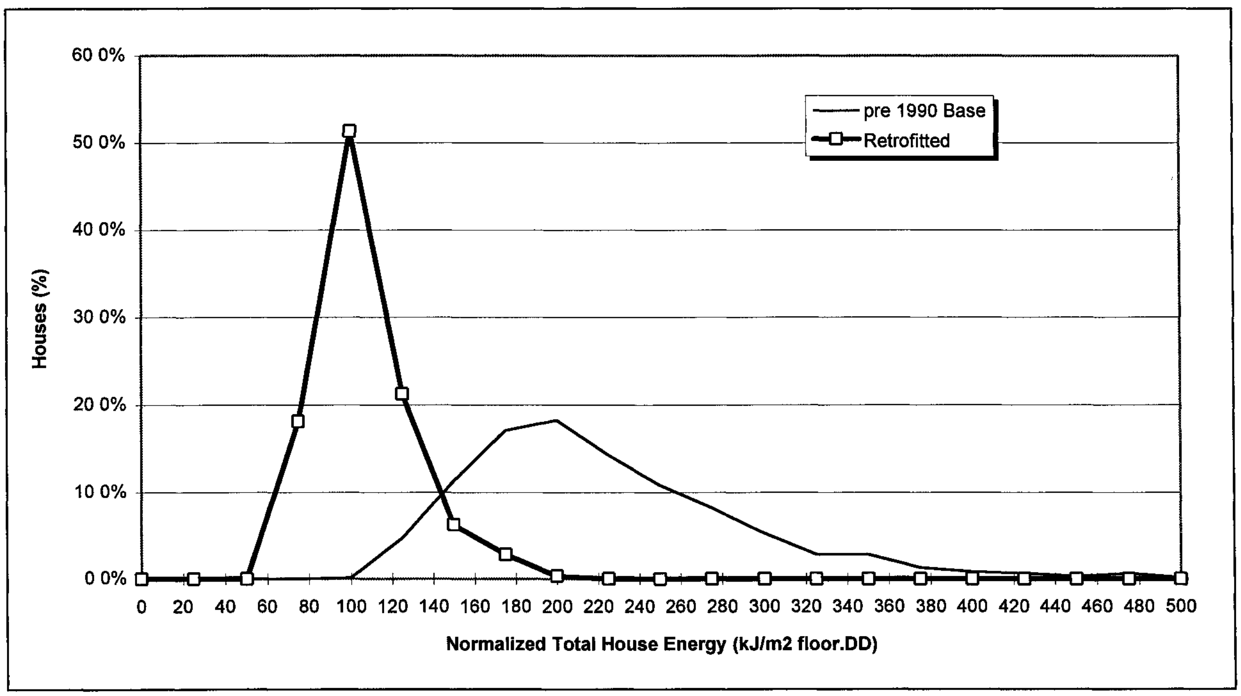
Figure 5.3 Residential Retrofits Performed with Maximum Economic Criteria of $12/GJ, (608 houses retrofitted)



In each region, LOW level retrofits raised all housing to approximately 1989 levels of new housing (except above grade wall cavities only filled with insulation), MID level retrofits to approximately the level of new housing projected for 1996 - National Energy Code (NECH ver. 2.0) and HIGH level retrofits to approximately the NECH level plus 30% (+6 ER for windows).

HIGH level retrofits result in normalized energy use (kJ/m^2 floor area - degree day) that is comparable to the R-2000 budget for new houses (however they may not comply with the R-2000 standard in all respects). While higher performance is undoubtedly possible for individual houses - as shown by the spread in results in Figure 5.4, this probably represents a practical upper limit for retrofitting the majority of the housing stock.

Figure 5.4 Normalized Energy Use: HIGH scenario (run H12C01)



The averages of key output parameters (energy use, pollutant generation, embodied values of energy and pollutants, retrofit cost, etc.) for each house were used to extrapolate the results for each run to the 1989 Canadian housing stock.

The results for the HIGH level retrofit with a $12 per GJ economic criteria (run H12C01), are shown in the tables 5.3 to 5.6. See Appendix C.1 for detailed outputs for the other runs.

Table 5.3 summarizes average characteristics of the base and upgraded houses, by region and age for this HIGH level retrofit scenario (H12C01).

Table 5.3 also shows that, for this run, 6% of the upgraded houses had total ventilation (infiltration plus mechanical ventilation) that exceeded 0.4 air changes per hour from October to April. This was in spite of the fact that this run used an optimal ventilation control that was supposed to maintain an monthly average of 0.3 air changes per hour total. Some of these houses were still sufficiently loose that average **natural air change** rates exceeded 0.3 air changes per hour in some months.

Table 5.3 also shows that 16% of the houses were interior retrofits, and that none of these houses had average air change rates of less than 0.25 air changes per hour [36]. Fan depressurization tests (not included in the costs) would probably be required for some or all of the high level retrofits to "tune" the control system, to reduce the potential for over or under ventilating.

Table 5.4 shows the reduction of carbon dioxide, carbon monoxide, nitrogen oxides and methane due to **operation** by province/region and age category. For this run, there was a potential of a 51% reduction in source carbon dioxide emissions due to operation, on a national basis.

Table 5.4c shows a summary of embodied pollutants associated with the retrofits to the houses - except for carbon monoxide, all have paybacks of less than one year.

Since the older houses (pre 1921 and 1921 to 1945) were generally of lower thermal efficiency initially, the reductions in emissions associated with retrofits of these houses was greatest - with a national average of 60% (Table 5.4a).

Table 5.5 shows a reduction in operating energy of 45%. Note that this is a source value - including energy by utilities for electrical generation and transmission.

Table 5.6 summarizes the retrofit costs by region and age, with a national energy related cost of over 59 billion dollars and a total cost of over 122 billion dollars. These results should be taken as representative of what is **technically feasible**, since **all** houses meeting the economic criteria of an ELCEC equal to $12/GJ were assumed to be retrofitted.

[36] These houses with interior retrofits could have the highest levels of new, pollutant generating, materials added to the interior spaces However, proper selection of low emission materials could minimize these harmful pollutants, AND the requirement for additional ventilation

Table 5.3 Retrofit of Canadian Houses: HIGH Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: H12C01

Base

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:
Space heating: upgrade
Domestic hot water: upgrade
Ventilation control: iaq_opt

Operations:
DHW: 20% reduction
Utilities: 20% reduction

Region	Age	Number of Houses Retrofitted	Volume (m³)	Floor area (incl bsmt) (m²)	Natural air change Base ac/h	Natural air change Upgrade ac/h	Total air change Base ac/h	Total air change Upgrade ac/h	Ventilation more than 0.4 ac/h	Interior retrofits: Ventilation less than 0.25 ac/h**	Interior retrofits: % of stock	Walls Base RSI	Walls Upgrade RSI
B C	<1921	9	478	186	0 70	0 32	0 70	0 34	10%	0%	0%	1 27	3 24
	1921-45	12	458	182	0 60	0 31	0 60	0 33	5%	0%	0%	1 45	3 29
	1946-60	24	441	165	0 53	0 33	0 53	0 35	9%	0%	0%	1 81	3 26
	1961-70	19	514	190	0 44	0 28	0 44	0 31	3%	0%	0%	1 97	3 24
	1971-80	6	553	181	0 39	0 31	0 39	0 33	6%	0%	0%	2 20	3 27
	>1981	18	687	268	0 21	0 17	0 53	0 25	0%	0%	0%	2 35	3 24
Prairies	<1921	11	407	150	0 54	0 21	0 54	0 29	0%	0%	9%	2 06	3 64
	1921-45	16	369	136	0 47	0 19	0 47	0 28	0%	0%	13%	2 10	4 13
	1946-60	41	417	155	0 31	0 19	0 31	0 28	2%	0%	7%	1 98	3 72
	1961-70	45	495	181	0 27	0 16	0 27	0 26	0%	0%	8%	2 12	3 72
	1971-80	37	485	183	0 20	0 14	0 20	0 27	0%	0%	5%	2 33	4 03
	>1981	40	593	226	0 22	0 13	0 44	0 26	0%	0%	0%	3 62	3 64
Ontario	<1921	14	520	186	0 78	0 37	0 78	0 40	50%	0%	100%	1 43	3 23
	1921-45	19	416	150	0 61	0 30	0 61	0 34	5%	0%	100%	1 49	3 19
	1946-60	49	507	192	0 37	0 22	0 37	0 28	2%	0%	0%	1 71	3 30
	1961-70	23	529	200	0 33	0 21	0 33	0 27	0%	0%	0%	2 05	3 68
	1971-80	21	475	182	0 28	0 19	0 28	0 27	0%	0%	4%	2 21	3 70
	>1981	41	847	321	0 19	0 16	0 24	0 26	0%	0%	0%	2 55	3 31
Quebec	<1921	6	506	187	0 60	0 22	0 60	0 28	0%	0%	14%	2 72	6 01
	1921-45	11	442	163	0 54	0 20	0 54	0 29	9%	0%	18%	2 01	6 51
	1946-60	44	476	173	0 40	0 19	0 40	0 28	4%	0%	33%	1 96	6 12
	1961-70	18	451	178	0 32	0 18	0 32	0 27	0%	0%	23%	2 28	5 99
	1971-80	15	441	160	0 28	0 17	0 28	0 27	0%	0%	14%	2 43	6 30
	>1981	2	471	192	0 15	0 21	0 15	0 27	0%	0%	0%	3 64	5 09
Maritimes	<1921	3	367	138	0 79	0 35	0 79	0 36	33%	0%	0%	2 50	3 60
	1921-45	5	338	127	0 89	0 34	0 89	0 36	40%	0%	0%	2 08	4 84
	1946-60	11	433	157	0 60	0 26	0 60	0 31	18%	0%	27%	1 90	5 66
	1961-70	14	470	166	0 49	0 23	0 49	0 30	0%	0%	57%	1 79	6 12
	1971-80	24	463	174	0 37	0 20	0 37	0 27	0%	0%	9%	2 25	5 43
	>1981	10	625	239	0 17	0 15	0 44	0 25	0%	0%	0%	3 70	4 78
CANADA	<1921	43	455	169	0 68	0 30	0 68	0 34	28%	0%	48%	2 00	3 94
	1921-45	63	405	152	0 62	0 27	0 62	0 32	8%	0%	41%	1 83	4 39
	1946-60	169	455	168	0 44	0 24	0 44	0 30	5%	0%	10%	1 87	4 41
	1961-70	119	492	183	0 37	0 21	0 37	0 28	1%	0%	12%	2 04	4 55
	1971-80	103	483	176	0 30	0 20	0 30	0 28	1%	0%	6%	2 28	4 55
	>1981	111	644	249	0 19	0 16	0 36	0 26	0%	0%	0%	3 17	4 01
	Total:	**608**											
	Average:*		489	183	0 43	0 23	0 46	0 30	6%	0%	16%	2 20	4 31

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Table 5.3...Retrofit of Canadian Houses: HIGH Scenario

Cutoff for retrofit:

$12.00 /GJ equiv

Base

Region	Age	Ceiling Base RSI	Ceiling Upgrade RSI	Above grade Bsmt Base RSI	Above grade Bsmt Upgrade RSI	Windows (south) Base RSI	Windows (south) Upgrade RSI	Window /floor area %	Energy Related Costs Retrofit Unit Cost $	Energy Related Costs Total Cost (10^6 $)	Life cycle Unit Energy Cost ($/GJ/30y)
B C	<1921	1 88	9 42	0 91	3 31	0 26	0 42	9%	14,532	394	7 32
	1921-45	3 05	8 00	0 84	3 21	0 26	0 38	11%	14,331	837	8 63
	1946-60	3 72	8 85	1 13	3 07	0 28	0 39	14%	14,210	1,819	9 15
	1961-70	3 41	9 18	1 37	3 02	0 28	0 43	13%	13,652	1,194	9 35
	1971-80	3 53	8 23	1 35	3 00	0 29	0 40	13%	13,683	1,086	7 61
	>1981	4 60	7 64	1 17	2 78	0 36	0 36	12%	10,767	1,199	6 67
									Subtotal:	**6,530**	
Prairies	<1921	3 38	9 41	0 64	3 39	0 37	0 66	8%	12,673	1,406	5 64
	1921-45	3 62	9 51	0 56	3 44	0 36	0 59	8%	12,756	2,150	6 78
	1946-60	3 98	9 14	0 95	3 18	0 37	0 59	9%	12,513	3,429	7 30
	1961-70	3 24	8 51	0 95	3 00	0 35	0 54	9%	12,415	2,130	7 12
	1971-80	3 58	8 78	1 35	2 82	0 36	0 56	9%	13,116	3,113	8 66
	>1981	6 96	8 32	1 88	2 85	0 49	0 62	7%	6,560	1,000	4 03
									Subtotal:	**13,228**	
Ontario	<1921	3 37	9 47	0 65	3 52	0 35	0 48	9%	14,117	4,144	4 85
	1921-45	4 24	8 97	0 72	3 30	0 36	0 48	10%	11,527	2,815	6 38
	1946-60	4 11	8 60	0 75	3 19	0 37	0 47	10%	13,049	6,086	8 47
	1961-70	3 62	8 40	0 91	3 11	0 37	0 47	11%	13,694	3,282	9 00
	1971-80	3 98	8 02	1 35	2 76	0 35	0 48	11%	12,931	3,203	9 88
	>1981	5 69	7 54	1 44	2 45	0 36	0 49	8%	10,634	3,782	7 07
									Subtotal:	**23,311**	
Quebec	<1921	2 94	11 70	0 99	3 20	0 38	0 46	7%	14,250	1,562	7 41
	1921-45	3 68	11 70	0 90	3 49	0 38	0 48	8%	16,005	1,484	6 93
	1946-60	4 23	11 70	1 07	3 23	0 37	0 47	10%	14,639	3,159	7 53
	1961-70	3 67	11 70	1 31	2 95	0 37	0 48	11%	14,479	1,556	8 45
	1971-80	3 77	11 54	1 39	2 96	0 37	0 48	11%	13,928	1,699	9 10
	>1981	5 84	11 70	1 92	3 14	0 39	0 48	14%	9,583	95	10 02
									Subtotal:	**9,555**	
Maritimes	<1921	2 54	9 36	1 19	2 95	0 33	0 47	11%	11,382	1,189	5 20
	1921-45	1 73	10 30	0 92	3 39	0 35	0 49	9%	14,112	1,012	5 51
	1946-60	3 07	11 06	0 82	3 42	0 35	0 48	9%	14,228	1,654	5 61
	1961-70	2 89	11 53	0 89	3 30	0 36	0 49	9%	13,798	1,075	6 77
	1971-80	3 27	11 02	1 33	3 12	0 35	0 49	10%	13,513	1,209	7 79
	>1981	6 14	11 70	2 50	3 13	0 37	0 52	8%	8,266	465	4 00
									Subtotal:	**6,604**	
CANADA	<1921	2 82	9 87	0 88	3 27	0 34	0 50	9%	13,391	8,695	6 08
	1921-45	3 26	9 69	0 79	3 36	0 34	0 48	9%	13,746	8,297	6 84
	1946-60	3 82	9 87	0 95	3 22	0 35	0 48	10%	13,728	16,148	7 61
	1961-70	3 36	9 86	1 08	3 07	0 35	0 48	11%	13,608	9,237	8 14
	1971-80	3 62	9 52	1 35	2 93	0 34	0 48	11%	13,434	10,311	8 61
	>1981	5 85	9 38	1 78	2 87	0 39	0 49	10%	9,162	6,541	6 36
	Total:								**Total:**	**59,229**	
	Average:	3 79	9 70	1 14	3 12	0 35	0 49	10%	**$12,845** (unweighted)		7 27

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Tables 5.4 to 5.6 summarize the results, with respect to emissions, energy and cost, of the retrofit run H12C01, performed with REES, using a database of 765 single detached houses from across Canada.

Table 5.4a Reduction in Carbon Dioxide Emissions due to Operations (run H12C01)

Age	Housing Stock	B.C. (kilotonnes/y)	Prairies (kilotonnes/y)	Ontario (kilotonnes/y)	Quebec (kilotonnes/y)	Maritimes (kilotonnes/y)	Canada (kilotonnes/y)	(%)
<1921	666,980	159	801	3,218	567	1,026	**5,772**	**60%**
1921-45	684,173	311	1,023	1,637	888	902	**4,761**	**60%**
1946-60	1,356,041	657	1,504	2,561	1,397	1,257	**7,377**	**53%**
1961-70	875,044	363	1,034	1,178	526	620	**3,720**	**46%**
1971-80	1,156,834	392	1,031	983	525	482	**3,412**	**39%**
>1981	919,050	524	859	1,624	1	550	**3,558**	**43%**
Total	5,658,122	2,406	6,252	11,201	3,904	4,837	**28,600**	**51%**

Table 5.4b Reduction in Pollutant Emissions due to Operations (run H12C01)

Age	Housing Stock	Retrofit (%)	CH4 (kilotonnes/y)	CO (kilotonnes/y)	NOx (kilotonnes/y)
<1921	666,980	96%	0.04	0.54	45.1
1921-45	684,173	86%	0.04	0.1	38.2
1946-60	1,356,041	88%	0.07	0.28	51.7
1961-70	875,044	79%	0.04	0.26	21.5
1971-80	1,156,834	70%	0.05	0.34	12.3
>1981	919,050	71%	0.07	0.4	4.8
Total	5,658,122	81%	0.31	1.92	173.6

Table 5.4c Embodied Pollutants associated with Retrofits (run H12C01)

Age	Housing Stock	CO2 (kilotonnes)	payback (years)	CH4 (kilotonnes)	payback (years)	CO (kilotonnes)	payback (years)	NOx (kilotonnes)	payback (years)
<1921	666,980	1,689	0.3	0.04	0.9	2.3	4.3	4.7	0.1
1921-45	684,173	1,550	0.3	0.03	0.9	2.3	23.1	4.3	0.1
1946-60	1,356,041	3,132	0.4	0.06	0.9	3.8	13.7	8.3	0.2
1961-70	875,044	1,832	0.5	0.04	0.9	2.1	8.1	4.9	0.2
1971-80	1,156,834	2,120	0.6	0.04	0.9	2.3	6.8	5.6	0.5
>1981	919,050	1,605	0.5	0.03	0.5	2.1	5.2	4.1	0.8
Total	5,658,122	11,927	0.4	0.25	0.8	14.9	7.8	31.9	0.2

Table 5.5 National Energy associated with Retrofits (run H12C01)

Age	Housing Stock	Retrofit	Operating Savings		Retrofit Energy	Payback
		(%)	(PJ/year)	(%)	(PJ)	(years)
<1921	666,980	96%	96.7	56%	43.7	0.5
1921-45	684,173	86%	76.7	54%	39.2	0.5
1946-60	1,356,041	88%	128.6	48%	81.4	0.6
1961-70	875,044	79%	69.7	41%	48.1	0.7
1971-80	1,156,834	70%	72.7	35%	55.4	0.8
>1981	919,050	71%	68.6	37%	43.8	0.6
Total	5,658,122	81%	**513**	**45%**	**312**	0.6

Table 5.6 National Energy-related Retrofit Costs (run H12C01)

Age	Housing Stock	Retrofit	B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	**Canada** Total Cost
		(%)	(10^6 $)	(10^6 $)	(10^6 $)	(10^6 $)	(10^6 $)	(10^6 $)	(10^6 $)
<1921	666,980	96%	394	1,406	4,144	1,562	1,189	8,695	16,825
1921-45	684,173	86%	837	2,150	2,815	1,484	1,012	8,297	15,931
1946-60	1,356,041	88%	1,819	3,429	6,086	3,159	1,654	16,148	32,672
1961-70	875,044	79%	1,194	2,130	3,282	1,556	1,075	9,237	19,249
1971-80	1,156,834	70%	1,086	3,113	3,203	1,699	1,209	10,311	21,332
>1981	919,050	71%	1,199	1,000	3,782	95	465	6,541	16,301
Total	5,658,122	**81%**	6,530	13,228	23,311	9,555	6,604	**59,229**	**122,310**

Table 5.7 summarizes the results of several runs performed with REES, using a database of 765 single detached houses from across Canada.

Table 5.7a Single-Detached Housing Retrofits - Descriptions

Run	Run ID	Retrofit Level	Minimize impact on[1]:	Cost Criteria[2] ($/GJ eff.)	Ventilation Control	Summer Fans	Remarks
1	H99C01	HIGH	Cost	unlimited	optimum	off	see Appendix C
2	**H12C01**	HIGH	Cost	$12.00	optimum	off	< see Tables 5.4 to 5.6, & see Appendix C
3	H12C02	HIGH	Cost	$12.00	continuous	off	see Appendix C
4	H12C04	HIGH	Cost	$12.00	optimum	off	unrestricted side yard
5	M12C01	MID	Cost	$12.00	optimum	off	see Appendix C
6	L12C01	LOW	Cost	$12.00	optimum	off	see Appendix C

[1] *minimize environmental impact* meant that cellulose insulation was used in wall retrofits and, for HIGH level retrofits, that a solar domestic water heater was used *Minimize cost* meant that fiberglass insulation was used in wall retrofits, wherever technically feasible..

[2] Retrofit houses only if the life-cycle effective retrofit energy cost less than value shown
ELCEC = (Energy-related Retrofit cost)/(Present Worth Factor x Annual Source Energy Savings - Source Retrofit Embodied Energy)

Table 5.7b Single-Detached Housing Retrofits - Results summary

Run	Run ID	Housing stock retrofitted (%)	Operating Carbon Dioxide Reduction (kilotonnes/yr)	Operating Carbon Dioxide Emissions[1] (% 1989)	Operating Energy Reduction (PJ/yr)	Operating Energy (% 1989)	Retrofit Embodied Energy (PJ)	Energy Related Retrofit Cost (billions of $)
1	H99C01	100%	30,460	46%	562	51%	381	71.8
2	**H12C01**	81%	28,600	49%	513	55%	312	59.2
3	H12C02	74%	24,706	56%	436	62%	280	52.9
4	H12C04	80%	28,584	50%	511	55%	320	59.8
5	M12C01	82%	22,014	61%	389	66%	224	38.4
6	L12C01	89%	13,897	75%	240	79%	66	16.1

[1] Note that these are **levels with respect to 1989**, however **Tables 5.4 and 5.5** show **reductions** of emissions and energy with respect to original levels (for example run H99C01 reduced CO2 emissions by 54%, so emissions are equal to 46% of original levels).

The effect of eliminating side yard restrictions (H12C04 - compare to H12C01) was minimal under the scenario employed here - there were only a limited number of "thick-wall" retrofits.

These levels of reduction in energy use and carbon dioxide generation could be **approached** with penetration rates approaching 100% and only if implemented very quickly. Over time, the existing housing stock will be demolished, thereby reducing the number of houses that can be retrofitted - see Tables 5.8 and 5.9 for projected reductions with longer term retrofit programs.

GHG emissions of the order of 50% of 1989 levels are possible only with the HIGH level scenarios.

Energy and Emissions Projections

The Toronto Protocol set goals for greenhouse gas emissions at 80% of 1988 levels by 2005 and 50% of 1988 levels by 2030. In order to project the results of the housing retrofit analysis carried out on the 1989 housing stock, projections of total housing, new house completions, demolitions and retrofits were performed to estimate the single-detached housing market through to the year 2030.

Single-detached housing completion projections were estimated (Appendix C.2), based on historical trends, and also accounting for an observed shift from single-detached to multi-family dwellings. This trend is greatest in Ontario and B.C.. As of 1994, new single detached houses represent 56% of housing unit completions nationally - down from an average of 63% for the 1984-1993 period[37]. This trend is likely to continue for the foreseeable future[38].

The following analysis is based on a 1989 Statistics Canada breakdown of housing by region, 1990 to 1995 actual single detached housing completions by region (67,619 for all of Canada in 1995), and **estimates** of future completions by region (for Canada, totals ranged from about 76,500 in 2000 to 63,200 in 2030). Based on historical trends, demolitions were assumed to average from 4% (Maritimes) to 14.3% (B.C.) - averaging 8% of new house completions nationally (App. C.2). Demolitions were assumed to be replaced by new houses. Retrofits were performed at a rate of about 2.7% of the retrofittable housing stock per year - sufficient to upgrade virtually all the retrofittable houses in the analyses in Table 5.7 by the year 2030 (for results of these projections, see Table 5.8).

Energy consumption and pollutant emissions for new houses were determined from values for the 1989 Base houses, multiplied by an "efficiency improvement" factor. The energy efficiency of **new houses** was assumed to improve by 10% in each five year period - resulting in energy consumption and pollutant emissions of 43% of 1989 levels by the year 2030 (better than current R-2000 houses). While an analysis of new house energy use is outside the scope of this analysis, this level of performance is achievable today (NRCan Advanced houses)[39].

[37] CMHC Canadian Housing Statistics (1994),

[38] personal communication from Helmut Pastrick, Regional Economist for CMHC

[39] Seven, level-B monitored, R-2000 houses showed total consumption averaging 138 kJ/m^2 floor/DD18C (82% of 1989 houses), while results for five occupied NRCan Advanced houses showed total consumption averaging 68 kJ/m^2 floor/DD18C (41% of 1989 houses)

Figure 5.5 Residential Greenhouse Gas Emission Projections

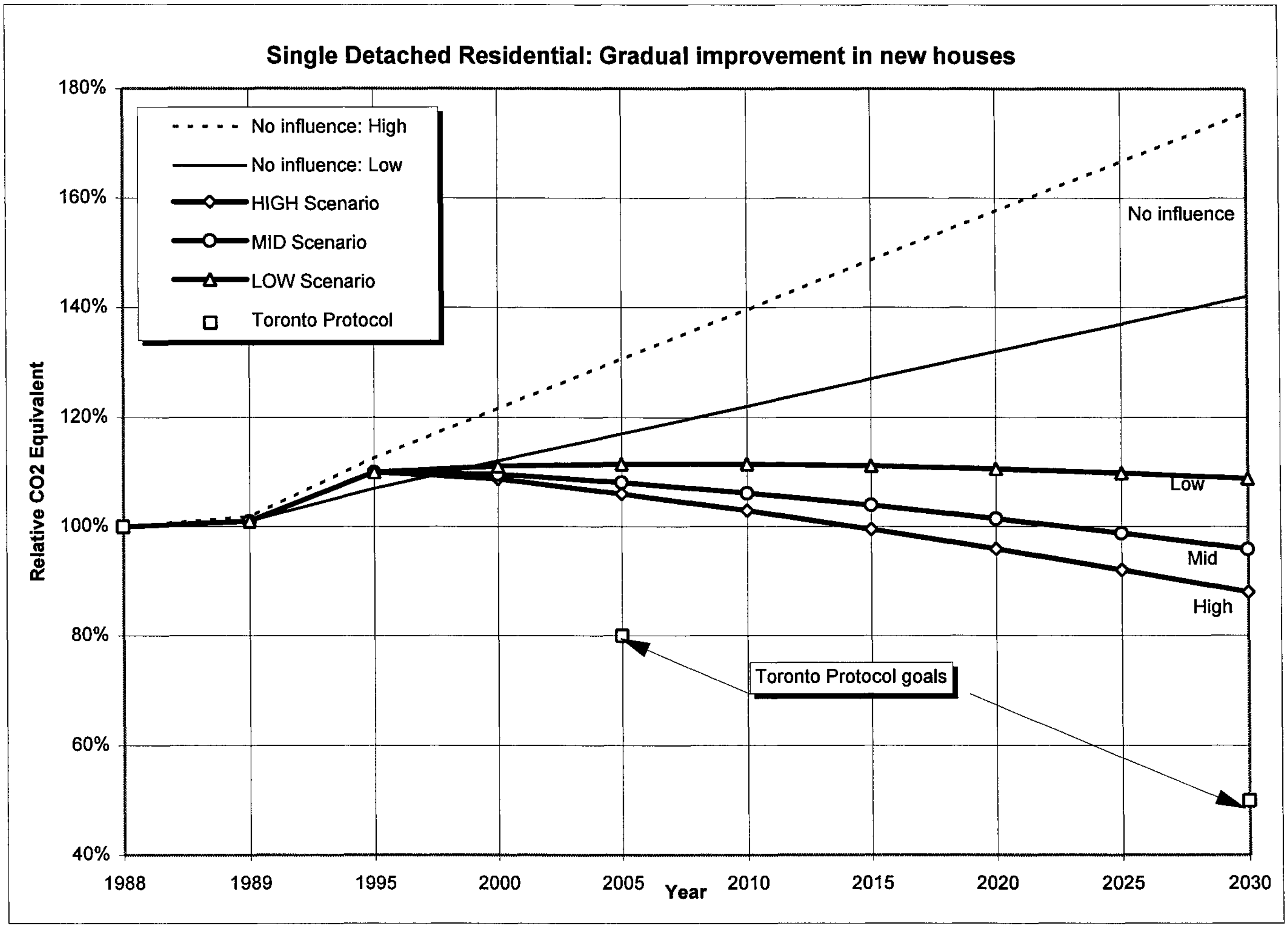


Table 5.8 Single-Detached Residential Retrofit Greenhouse Gas Projections

Scenario: New houses improvement: Year	HIGH Improve by: 10%/5years* CO2 Equivalent (%)	MID Improve by: 10%/5years CO2 Equivalent (%)	LOW Improve by: 10%/5years CO2 Equivalent (%)	Toronto Protocol Goals (%)	No Influence Options**: Low est. CO2 Equivalent (%)	High est. CO2 Equivalent (%)
1988	**100%**	**100%**	**100%**	**100%**	100%	100%
1989	101%	101%	101%		101%	102%
1995	110%	110%	110%		107%	113%
2000	109%	110%	111%		112%	122%
2005	**106%**	**108%**	**111%**	**80%**	**117%**	**131%**
2010	103%	106%	111%		122%	140%
2015	100%	104%	111%		127%	149%
2020	96%	101%	111%		132%	158%
2025	92%	99%	110%		137%	167%
2030	**88%**	**96%**	**109%**	**50%**	**142%**	**176%**
2030 (existing)	**60%**	**68%**	**80%**	< Existing housing stock only		

Notes:

* New housing (post 1989) assumed to have energy consumption and emissions reduced by 10% every five years

** No influence options - personal communication from Tom Hamlin, NRCan

Retrofits performed only on houses with a net energy equivalent cost of less than $12/GJ:

LOW scenario takes existing houses to regional 1989 levels of energy efficiency (85% of 1989 stock retrofitted)

MID scenario takes existing houses to NECH (ver. 2) levels of energy efficiency (80% of 1989 stock retrofitted)

HIGH scenario takes existing houses to NECH plus 30% levels of energy efficiency (78% of 1989 stock retrofitted)

Note that new houses built over the period were not retrofitted. Also, this analysis does not account for energy use or greenhouse gas emissions for multi-family dwellings (row house through to high-rise apartments).

Table 5.9 summarizes retrofit projections to the year 2030 for several retrofit scenarios. In addition to the original stock of houses (unchanged and retrofitted), these analyses include the effect of new, single-detached houses and also account for houses demolished during the period.

Table 5.9a Housing Retrofit Projections - Descriptions

Run	Run ID	Retrofit Level	Minimize impact on:	Cost Criteria[1] ($/GJ eff.)	Ventilation Control	Summer Fans	Remarks
2	**H12C01**	HIGH	Cost	$12.00	optimum	off	(see Tables 5.5, 5.6, and Appendix C)
5	M12C01	MID	Cost	$12.00	optimum	off	see Appendix C
6	L12C01	LOW	Cost	$12.00	optimum	off	see Appendix C

[1] Retrofit houses only if the life-cycle effective retrofit energy cost less than value shown; based on Effective Life-Cycle Energy Cost, ELCEC = (Energy-related Retrofit Cost)/(Present Worth Factor x Annual Source Energy Savings - Source Embodied Energy)

Table 5.9b Housing Retrofit GHG Projections

		from Table 5.7		to **year 2005**		to **year 2030**			
Run	Run ID	Housing stock to be retrofitted (%)	Operating CO_2 Emissions (% 1989)	Actual Houses retrofitted (%)	Equiv. CO_2 emissions[1] **(all houses)** (% 1988)	Actual Houses retrofitted[2] (%)	Equiv.CO_2 emissions **(all houses)** (% 1988)	Equiv. CO_2 emissions **(existing)** (% 1988)	Retrofit Costs ($millions/yr)
2	**H12C01**	81%	49%	26%	106%	77%	88%	**60%**	1,413
5	M12C01	82%	61%	27%	108%	78%	96%	68%	920
6	L12C01	89%	75%	27%	111%	85%	109%	80%	395

[1] "Equiv. CO_2 emissions" are total equivalent greenhouse gas emissions (GHG), calculated from CO_2 emissions + CO emissions x 3000 + NO_x emissions x 150 + CH_4 emissions x 63 (all emissions at source and, except for "Operating CO_2 emissions", include emissions due to retrofits)

[2] Most potential retrofits carried out by 2030; difference between "Actual Houses Retrofitted" (year 2030) and "Housing stock to be retrofitted" is due to houses that were demolished (replaced by new houses)

With a HIGH level of retrofit, **existing housing** (original plus retrofitted) have source carbon dioxide equivalent emissions of 60% of 1988 levels - close to the 50% target (run H12C01, Table 5.9b).

However, even though the HIGH level retrofit scenario results in houses that are comparable or exceed the performance of current new R-2000 houses (Figure 5.4), and new houses have steadily improving thermal performance (exceeding current R-2000 levels by 2030), carbon dioxide equivalent emissions from **all single-detached** houses are still projected to be above 1988 levels by 2005, and at 88% of 1988 levels by 2030 (run H12C01, Table 5.9 - similar results for other runs are in Appendix C.1).

Therefore, by the year 2030, if the environmental objectives of the Toronto Protocol are to be achieved, significant changes in housing will have to occur. Some of these include:

retrofits described in this analysis:

- retrofit of a significant fraction of the existing housing stock to high levels of performance to the -
  - envelope,
  - mechanical systems,
  - controls, and
  - appliances, lighting, outdoors
- reductions in energy use due to operational factors (reduced temperatures, reduced hot water usage, for example)

investigation of retrofit measures beyond the analysis performed in this study, for example:

- joining single-detached dwellings with buffered spaces (for storage, for example) to reduce side wall heat losses,
- use of co-generation units (probably most effective in multi-family dwellings with common heating systems),

A more integrated analytical approach that examines cross-program benefits and effects would also be useful, for example:

- continuing improvements in new housing energy standards (for example: energy standards that discourage the construction of large new houses could be used to encourage retrofits of existing houses, since they would be the only large houses left),
- a greater shift to more efficient multi-family dwellings,
- reduction of urban sprawl to reduce transportation energy.

These factors would impact on the number of single-family dwellings - both new and existing, and would therefore also impact on any retrofit program aimed at single-detached dwellings.

6 CONCLUSIONS and RECOMMENDATIONS

The REES software was found to be effective at determining cost-effective residential retrofit strategies.

In order to achieve the goals of carbon dioxide and energy reductions, it was necessary to perform whole-house retrofits - including all portions of the envelope, mechanical systems, appliances and operation. MID and HIGH level scenarios also included retrofits of ventilation systems. Several runs were carried out, encompassing a range of retrofit options (the following are all based on retrofits meeting an economic criteria of $12/GJ):

- HIGH scenario (approximately 30% higher than proposed National Energy Code for new House levels). **Result:** retrofitting 81% of existing housing stock reduced operating carbon dioxide emissions to 49% of 1989 levels, however, after factoring in new housing starts and demolitions of existing housing, total equivalent GHG emissions were reduced to only 88% of 1988 levels by the year 2030,
- MID scenario (bring existing housing up to the proposed NECH). **Result:** retrofitting 82% of existing housing stock reduced operating carbon dioxide emissions to 61% of 1989 levels, however after factoring in new housing starts and demolitions of existing housing, total equivalent GHG emissions were reduced to only 96% of 1988 levels by the year 2030, and
- LOW scenario (bring existing housing up to typical 1989 new house standards, except wall retrofits that were limited to filling empty wall cavities). **Result:** retrofitting 89% of existing housing stock reduced operating carbon dioxide emissions to 75% of 1989 levels, however after factoring in new housing starts and demolitions of existing housing, total equivalent GHG emissions were increased to 109% of 1988 levels by the year 2030.

GHG projections considered new housing starts and increasing performance levels for new houses. A demolition rate of existing stock equal to a national average 8% of new housing was assumed.

The goal of achieving a 50% reduction in carbon dioxide emissions from existing Canadian housing, while technically feasible, would require a penetration rate of over 80% of the existing housing market. At this rate of penetration, retrofits could be performed with an life-cycle effective cost of source energy saved equal to about $12 per GJ - about equal to the consumer price of oil and electric energy. If environmental-societal factors were incorporated into the analysis, the effective cost of source energy saved approaches the consumer price for natural gas. These analyses indicate that these retrofits are cost-effective now, from a societal perspective (although fuel price environmental multipliers or "carbon taxes" may be required).

Implementation of a retrofit program to achieve even a fraction of the 50% reduction goal would be a massive, multi-billion dollar undertaking, involving extensive consumer education, builder training, and very likely tax/incentive programs.

Regional sensitivities would be required to ensure the success of such a program. For example, reducing the use of hydro-generated electricity for internal appliances and lights in gas or oil heated houses can result in a net **increase** in carbon dioxide emissions - counter-productive to a program aimed at reducing carbon dioxide emissions (as distinct from reducing energy use).

Embodied energy and most embodied pollutants in the retrofits analyzed were repaid by reductions in operating energy and pollutants in less than one year. This indicates that the energy used and pollutants generated, in retrofitting houses, is a good investment toward future savings.

Adverse effects on indoor air quality, due to the materials in the retrofit and to tightening of the envelope, can be eliminated in most cases through appropriate selection of materials with reduced emissions and through the installation and operation of mechanical ventilation.

The wall retrofits developed as part of this study, should have no moisture condensation problems.

RECOMMENDATIONS:

Predicted energy savings should be compared with field measured energy savings for retrofitted houses, when they become available.

Further research should be carried out with respect to new housing starts, demolitions of existing houses, and additions to living space and their role in retrofits. Air-tightness of retrofitted houses should be confirmed by fan-door tests.

Develop algorithms to determine optimal OTC setpoints as a function of house air tightness and climate.

Research environmental impacts of adding hydroelectric and nuclear power generation systems to the present generation grid.

Carry out research into greenhouse gas driven "environmental factors" to determine the true (societal) costs of energy sources.

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Appendix A WALL RETROFIT OPTIONS

Thermal resistances are quoted for the various wall sections in Table 4.1

The figures that follow are the wall retrofit sections used in this study:

- A.1 Cavity fill (also applied in addition to interior or exterior retrofits)

Interior retrofits -

- A.2 Interior insulated sheathing
- A.3 Dynamic insulation interior retrofit
- A.4 Double wall interior retrofit

Exterior retrofits -

- A.5 Exterior insulated sheathing
- A.6 Dynamic wall with exterior air diffuser
- A.7 Exterior Wall Truss/Curtain wall

Note that basement retrofits are shown with RSI 3.88 (R22) batt insulation. In the simulations, batt and blown cellulose ranging from RSI 2.1 to RSI 4.9 were used (framing was spaced away from the wall).

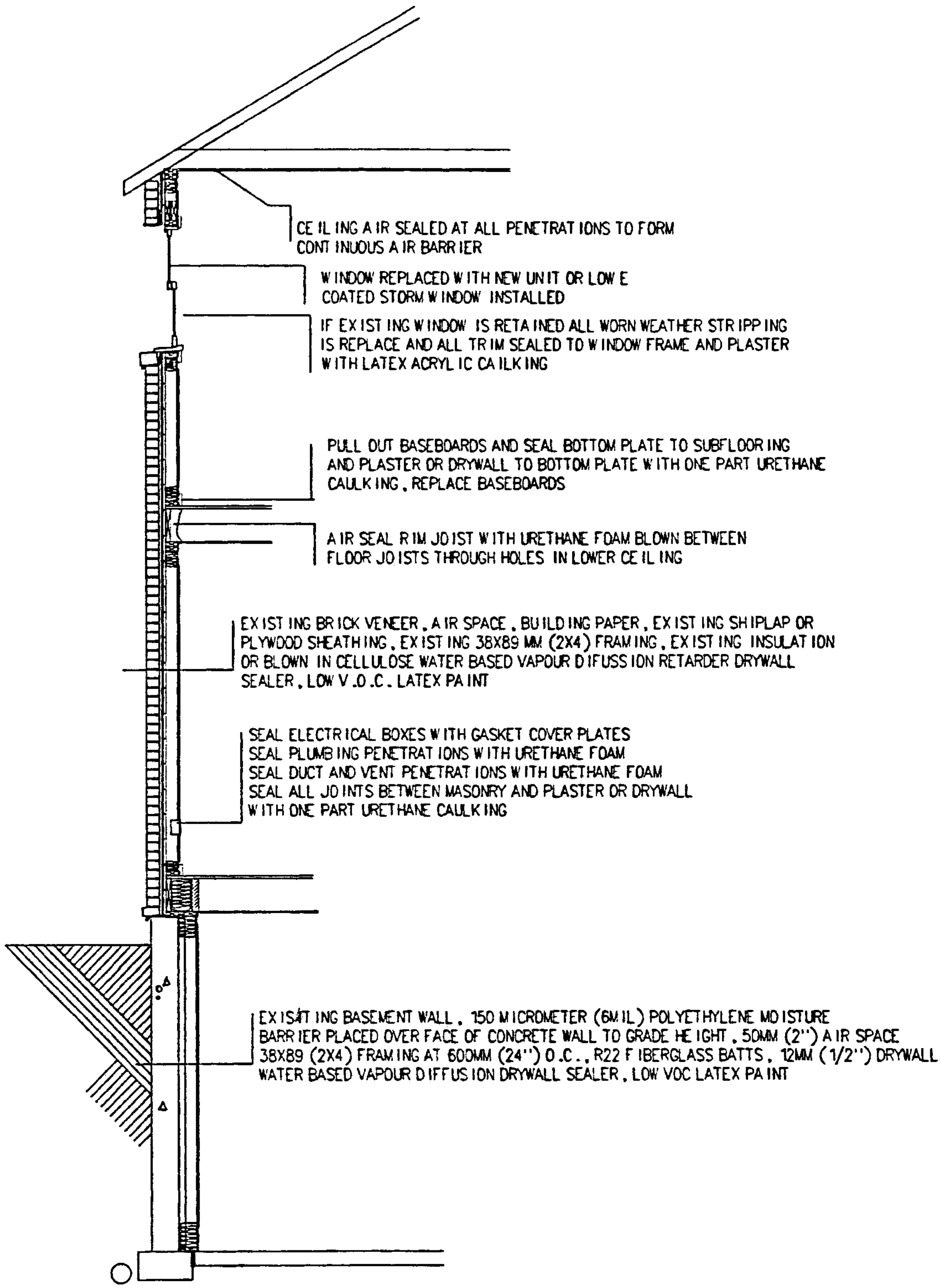

Figure A.1
EXISTING BRICK VENEER WALL CAVITY FILLED AND PENETRATIONS AND OPENINGS AIR SEALED
SCALE 1/4"=1'-0"

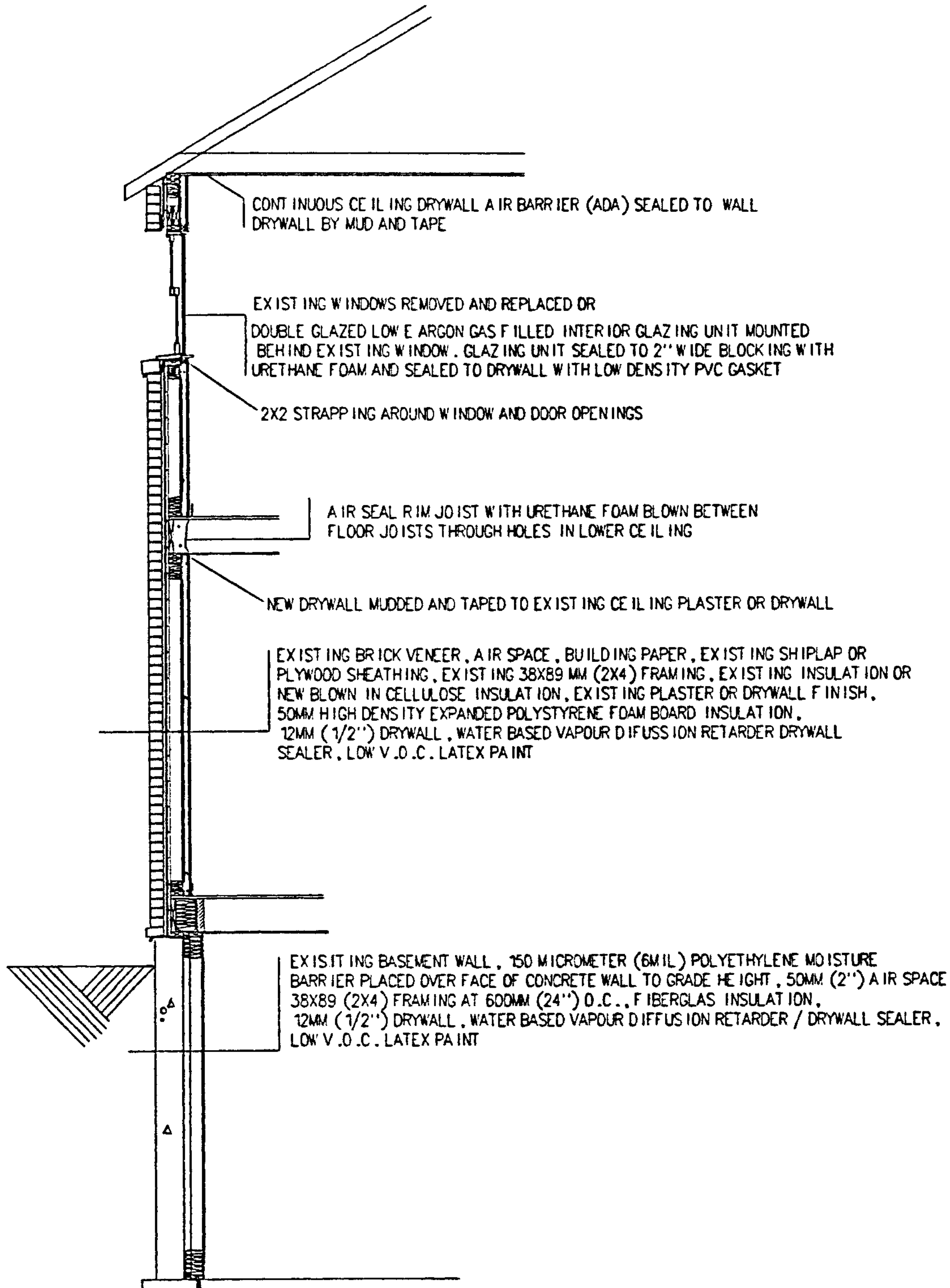

Figure A.2
INTERIOR INSULATED SHEATHING AS APPLIED TO AN EXISTING BRICK VENEER WALL

SCALE 1/4"=1'-0"

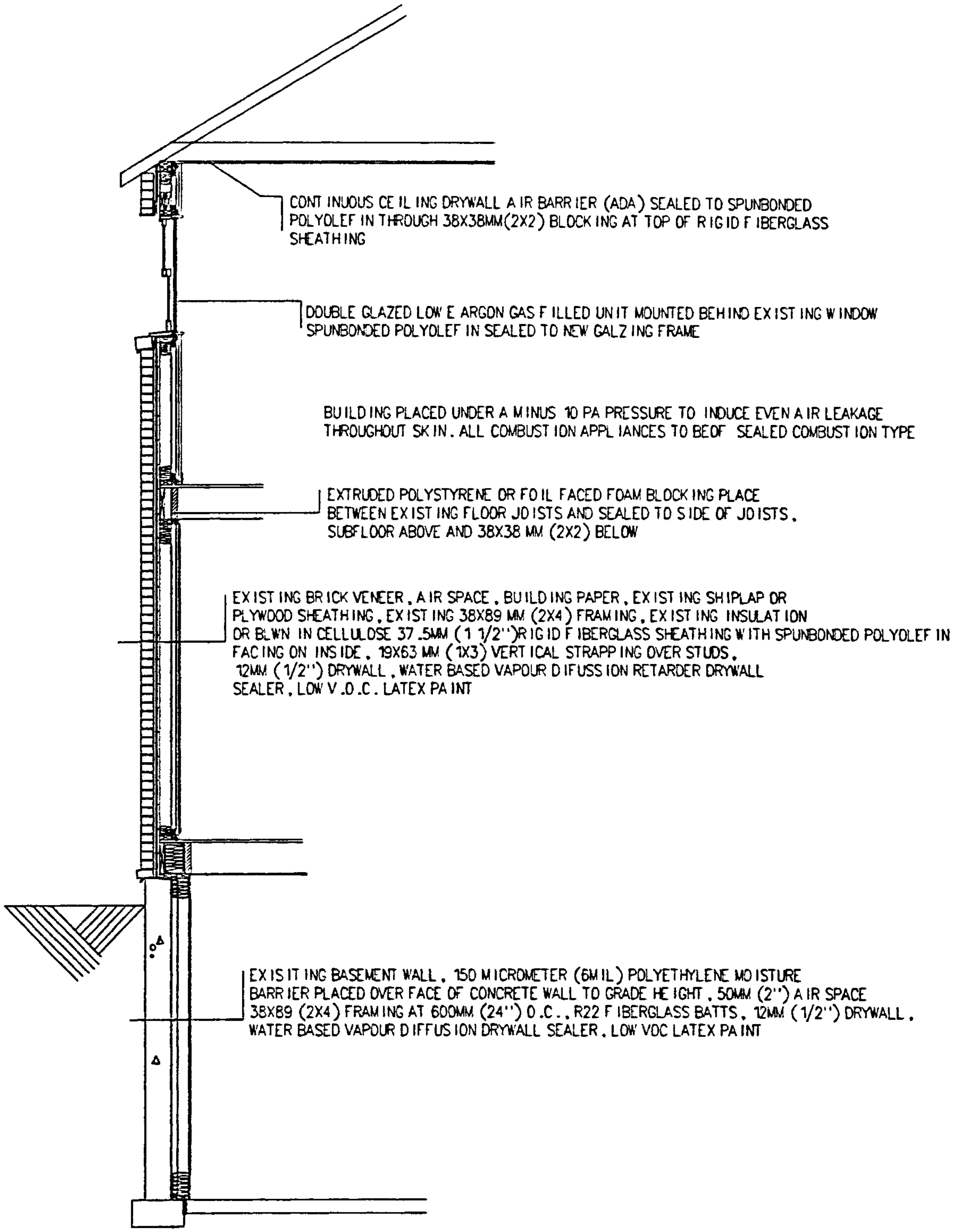

Figure A.3
DYNAMIC INSULATION AS APPLIED TO EXISTING BRICK VENEER WALL
SCALE 1/4"=1'-0"

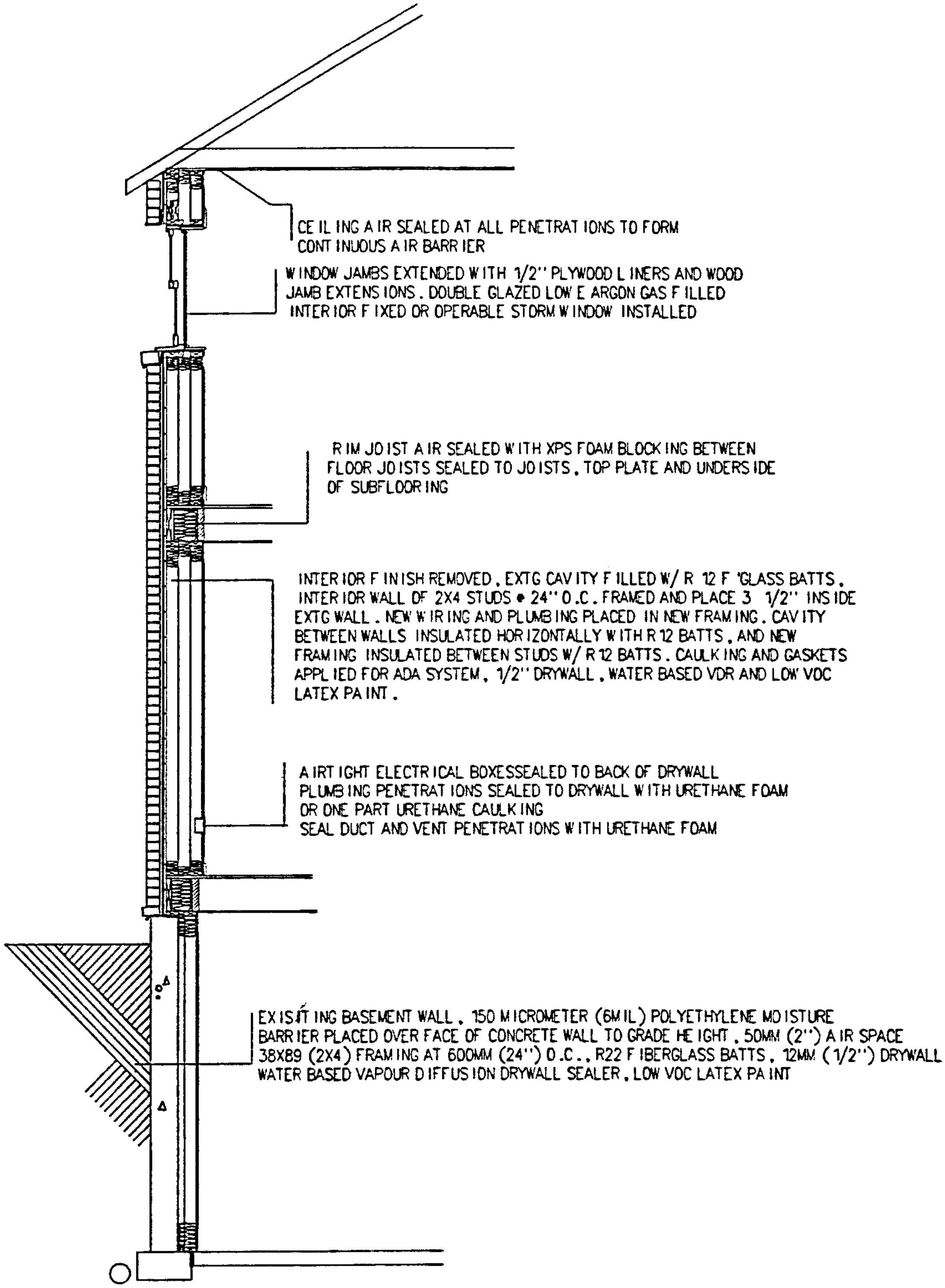

Figure A.4

DOUBLE WALL INTERIOR RETROFIT

SCALE 1/4"=1'-0"

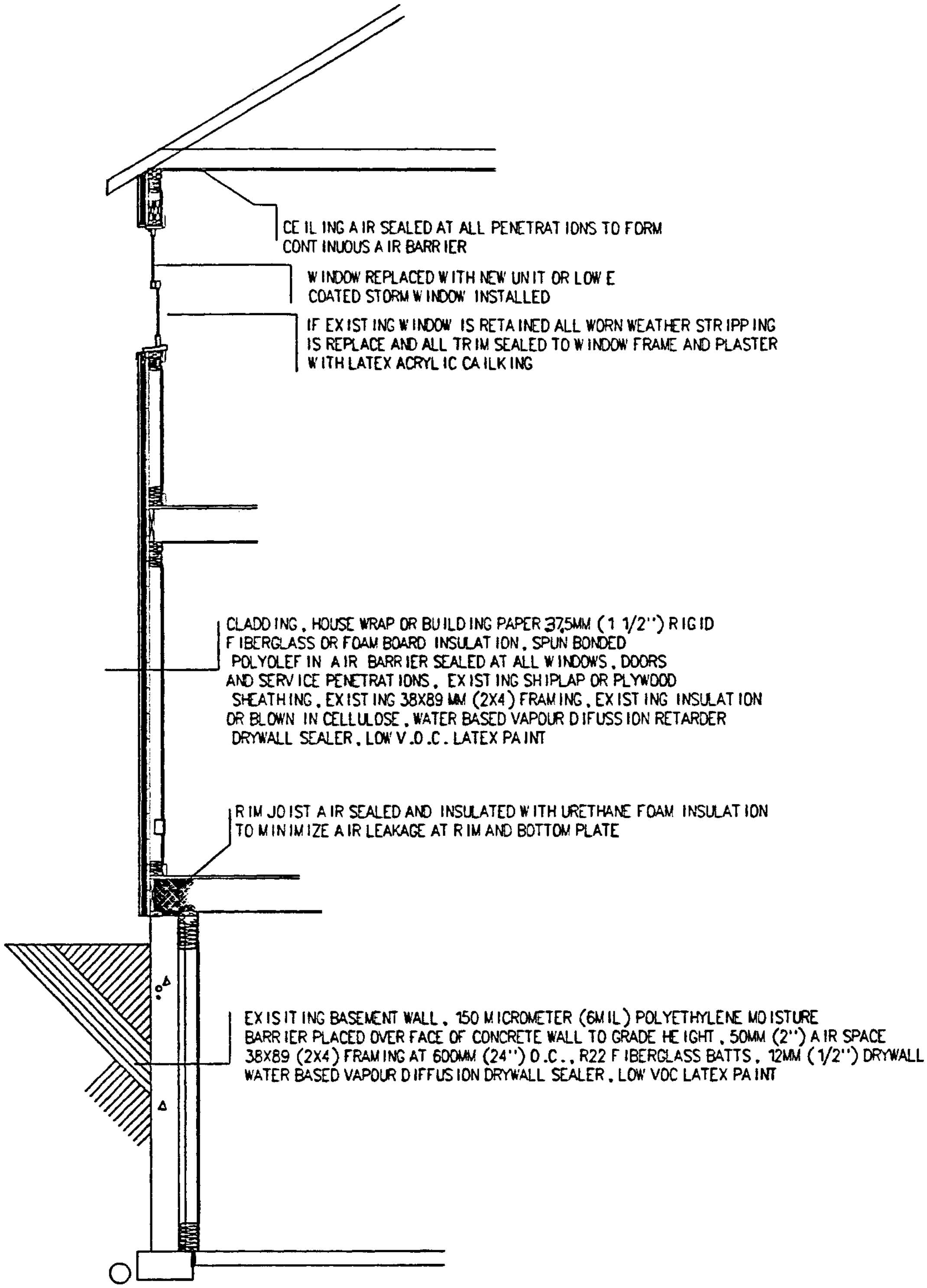

Figure A.5
EXTERIOR INSULATED SHEATHING RETROFIT
SCALE 1/4"=1'-0"

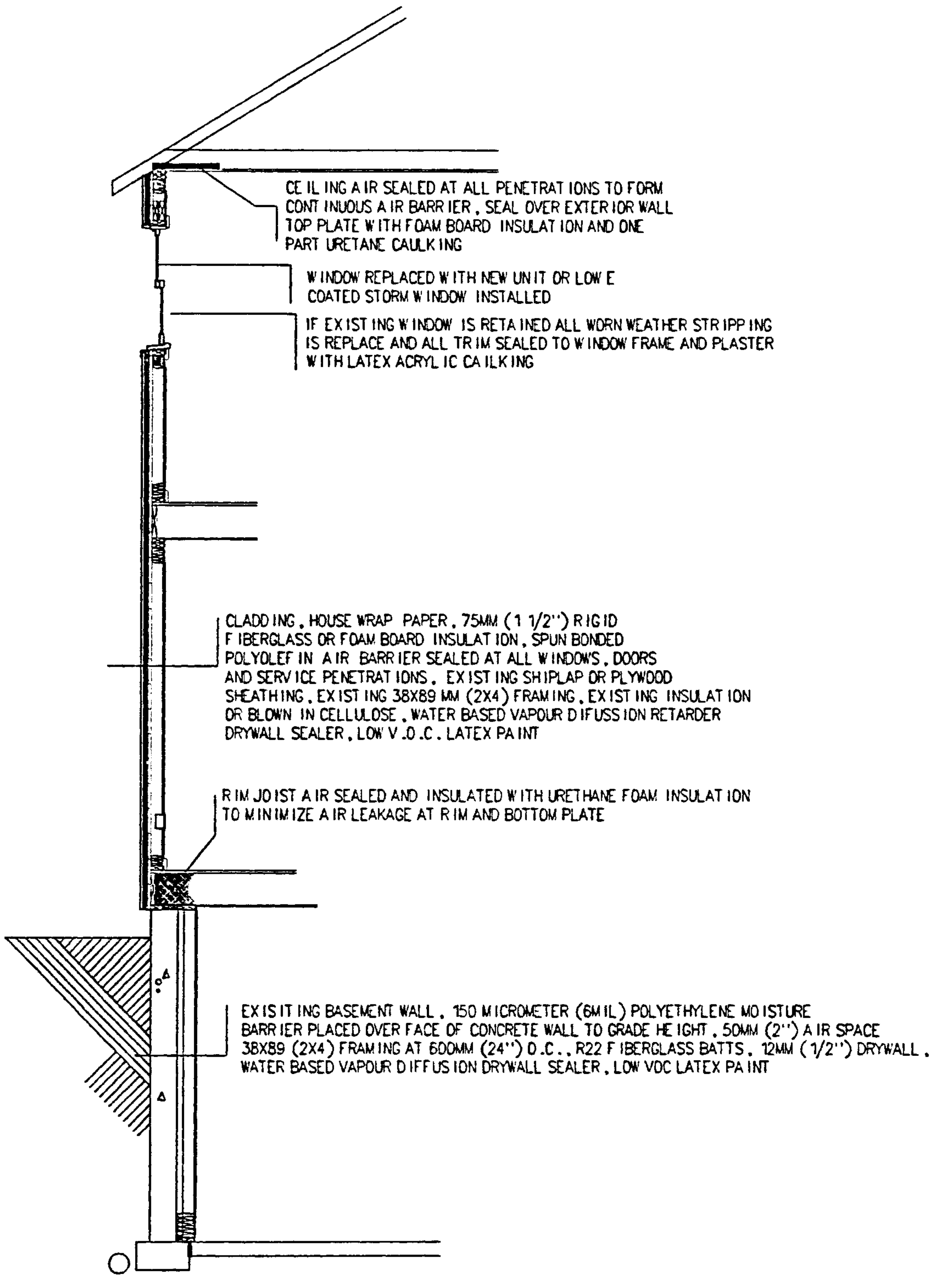

Figure A.6
DYNAM IC WALL W ITH EXTER IOR A IR D IFFUSER
SCALE 1/4"=1'-0"

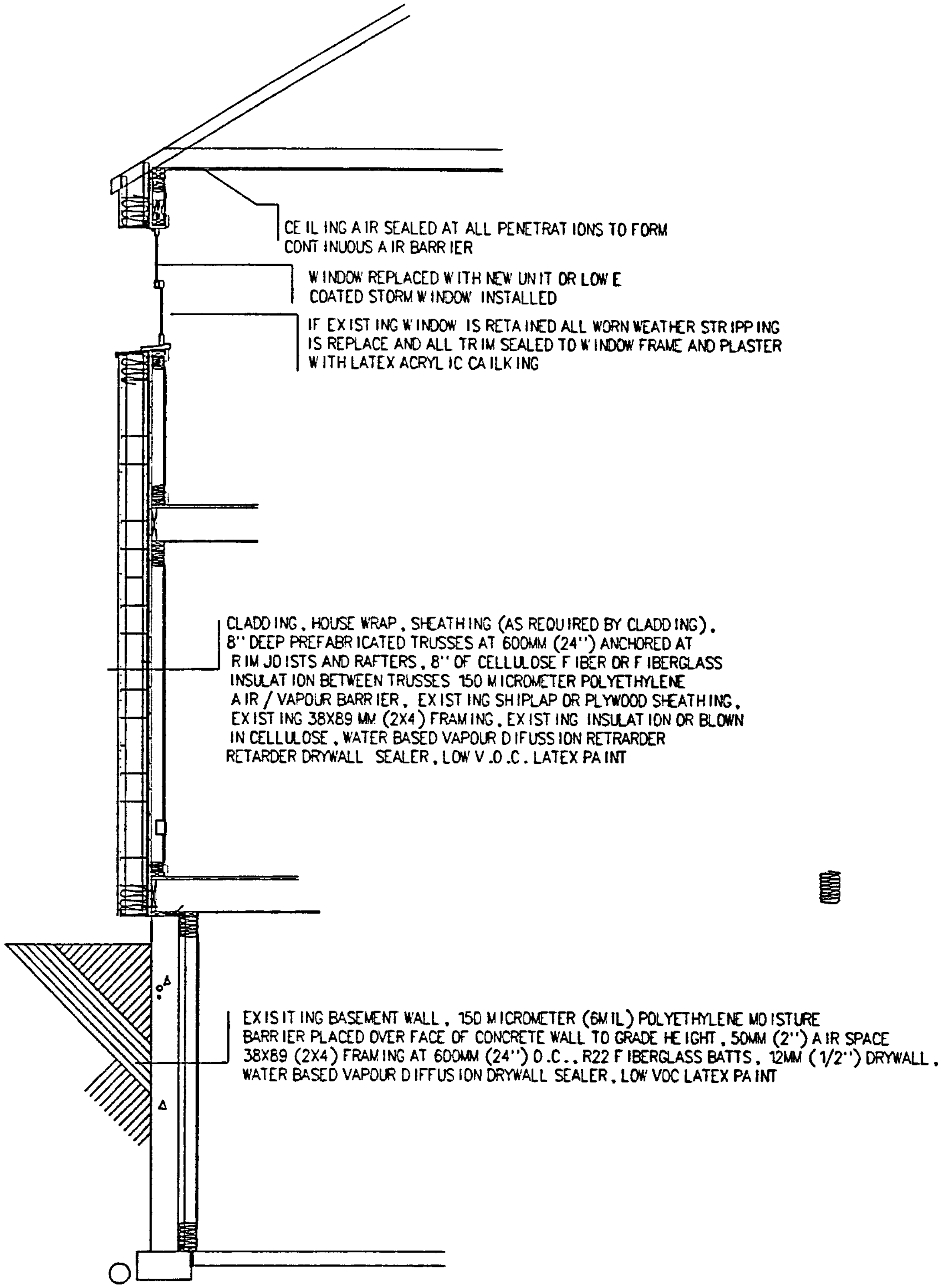

Figure A.7
EXTERIOR WALL TRUSS
SCALE 1/4"=1'-0"

Appendix B RESIDENTIAL ENERGY & ECONOMIC SIMULATOR - DOCUMENTATION

The thermal calculation "core" of the REES program is based on the algorithms of the HOT-2000 thermal simulation program (versions 5 through 7), including the following:

- Barakat solar Gain Load Ratio,
- Mitalas foundation model,
- AIM-2 infiltration model with Kiel-Wilson fan interaction model,
- selectable Davenport logarithmic or Power law modified local wind speeds, and
- a database of monthly weather for Canadian stations.

and some enhancements:

- ventilation system sizing using a "look-ahead" based on total ventilation rate minus shoulder season natural infiltration rates in April and October (a "pro" retrofitter strategy),
- alternate ventilation control systems, including outside temperature control (OTC) and optimized control (to result in a constant total air change rate,
- batch (database) or manual input
- modified OPTIMIZE[41] embodied energy & pollutant calculations (in conjunction with an updated database of embodied energy and pollutant values),
- calculation of energy use and pollutant generation, at the house and at source (accounting for regional energy source mix of electrical generation - see Table B.1)
- retrofit takeoff and costing model that incorporates a database of envelope sections (modified to account for characteristics of each house simulated),
- "extrapolation program" to determine regional and cross-Canada effects on the housing stock, and an
- "extrapolation program" to determine effects of various implementation rates through the year 2030, by accounting for projections of total housing stock, new housing and varying rates of retrofit of existing housing.

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[41] program developed by Sheltair Scientific, SAR engineering et al for CMHC

Table B.1 Electrical Generation Fuel Source Split

Gen. efficiency:	33%	33%	33%	100%[1]	100%	33%
Trans. efficiency:	95%	95%	95%	95%	90%	95%
Province/Region	**Coal**	**Oil**	**Gas**	**Nuclear**	**Hydro[2]**	**Other**
Newfoundland	0 0%	5 8%	0.0%	0.0%	94.2%	0 0%
Prince Edward Isl.	55.3%	44.7%	0 0%	0.0%	0.0%	0.0%
Nova Scotia	59.8%	28 2%	0 0%	0.0%	10.4%	1.6%
New Brunswick	9.3%	45 4%	0.0%	30 2%	13 5%	1 6%
MARITIMES	31.1%	31 0%	0 0%	7.5%	29.5%	0.8%
Quebec	0.0%	1.1%	0.0%	3.3%	95 6%	0.0%
Ontario	24.1%	1.0%	1.3%	46.1%	27.3%	0 2%
Manitoba	2.0%	0 0%	0.0%	0.0%	97.6%	0 3%
Saskatchewan	72 6%	0.0%	4.9%	0 0%	21 0%	1.5%
Alberta	78 8%	0.0%	15.9%	0 0%	3.7%	1.3%
PRAIRIES	51.1%	0 0%	6.9%	0.0%	40 8%	1 0%
British Columbia	0.0%	0.5%	8 6%	0.0%	88 6%	2.3%
CANADA	22.1%	7.5%	2.0%	15 4%	52.4%	0.5%

[1] Nuclear and hydro-electric systems are not 100% efficient, but we were not calculating source nuclear thermal or hydroelectric mechanical energy.

[2] Hydro electric systems are associated with the destruction of vegetation that stores carbon dioxide. No penalty has been assumed for this study.

Advantages to this spreadsheet-based system include the ability to easily modify the source code to try out new calculation methods (used to develop ventilation control options, for example),

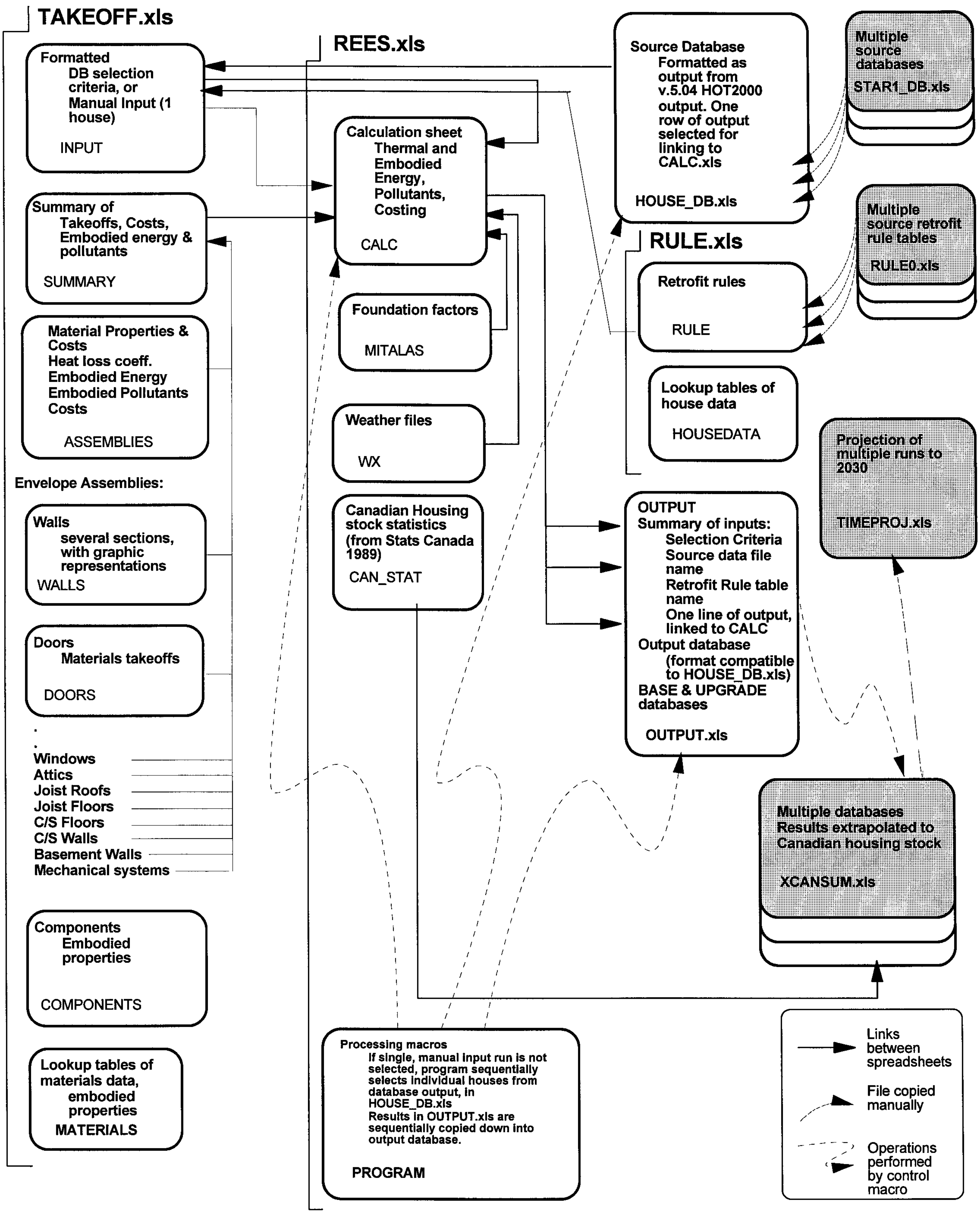
Some limitations of the program include the fact that mechanical system efficiencies are presently set at a fixed value (determined from HOT-2000, version 7.1 runs) for each type of system with archetype houses in several of the climate zones, that self shading of windows from building overhangs is not determined (though this can be entered as a monthly value, as part of overall shading), and that monthly energy balances are determined on the basis of a single outside temperature, rather than binned temperatures.

The following material describes the organization and inputs to the REES program[42]:

- organization chart
- available weather files
- sample base houses summary

[42] Note: System requirements to run REES are Microsoft Excel for Windows version 5. Recommended hardware configuration - pentium computer with 24 MB RAM (16 MB minimum) and 20 MB available hard drive space Run time on a 90 MHz pentium system is ~35 seconds/house or about 8 hours for the the 765 houses used in this study.

Residential Energy & Economic Simulator (REES)



Residential Energy & Economic Simulator
WEATHER FILES

Tin design: 21

Database of monthly weather 11-Mar-94

Weather data for one city is selected into the OUTPUT range after entering the appropriate City number (see table below) in the INPUT sheet
The Output is available as a Lookup table (LOOKWX) for use by the Calc sheet
Weather is long-term data from HOT-2000 (ver 6 02); **Note that data for all cities has NOT been entered (see Table below)**

Bold = estimated

No.	City	Province	Zone	DD18	ProvNo	Source	Latitude	(C) dTdesign	(C) TgrdS	(C) TgrdV	(C) Tcdbdes	(m) Zmet	SolIndex
British Columbia													
1	Abbotsford	BC	A	3150	1								
2	Castlegar	BC	D	3747	1	HOT2000	49 3	40	11 3	**8.5**	32	**20**	1 04
3	Fort Nelson	BC	B	7063	1								
4	Fort St John	BC	B	6119	1	HOT2000	56 23	57	5 1	**8.5**	26	**20**	0 95
5	Kamloops	BC	D	3756	1	HOT2000	50 7	46	10 3	**8.5**	34	**20**	1 07
6	Port Hardy	BC	C	3661	1								
7	Prince George	BC	B	5388	1	HOT2000	53 88	54	6 2	**12**	28	**20**	0 91
8	Prince Rupert	BC	D	4117	1	HOT2000	54 3	35	6 2	**8.5**	19	**20**	0 73
9	Smithers	BC	B	5290	1								
10	Summerland	BC	D	3318	1	HOT2000	49 57	31	12 3	11 9	33	**20**	1 06
11	Vancouver	BC	A	3007	1	HOT2000	49 25	28	11 3	8 5	26	20	0 96
12	Victoria	BC	C	3076	1	HOT2000	48 65	40	11 8	**8.5**	24	**20**	1 03
13	Williams's Lake	BC	B	5105	1								
13 1	user defined	BC			1								
Alberta													
14	Calgary	AB	A	5345	2	HOT2000	51 1	52	6 4	12 2	29	**20**	1 14
15	Edmonton	AB	B	5589	2	HOT2000	53 6	53	5 5	12 2	28	19	1 12
16	Fort McMurray	AB	C	6778	2								
17	Lethbridge	AB	A	4718	2	HOT2000	49 38	51	7 1	**12**	31	**20**	1 16
18	Rocky Mtn House	AB	B	5550	2	HOT2000	52 38	52	6 1	**12**	28	**20**	0 99
19	Suffield	AB	A	5102	2								
19 1	user defined	AB			2								
Saskatchewan													
20	Estevan	SA	A	5542	3	HOT2000	49 07	53	6 6	**12**	32	**20**	1 14
21	Prince Albert	SA	A	6562	3								
22	Regina	SA	A	5920	3	HOT2000	50 43	55	4 9	14 0	31	21	1 16
23	Saskatoon	SA	A	6077	3	HOT2000	52 17	56	5 3	12 7	30	20	1 10
24	Swift Current	SA	A	5482	3	HOT2000	50 27	53	5 6	11 4	32	**20**	1 12
25	Uranium City	SA	A	8210	3								
25 1	user defined	SA	A		3								
Manitoba													
26	Brandon	MA	A	6037	4	HOT2000	49 92	54	5 8	**12.4**	31	**20**	1 11
27	Churchill	MA	B	9213	4								
28	The Pas	MA	B	6852	4								
29	Thompson	MA	B	7930	4								
30	Winnipeg	MA	A	5889	4	HOT2000	49 9	54	6 1	12 4	30	23	1 10
30 1	user defined	MA			4								
Ontario													
31	Big Trout Lake	ON	B	7680	5								
32	Kingston	ON	A	4266	5	HOT2000	44 22	43	8 9	**11.7**	27	**20**	1 14
33	London	ON	A	4068	5	HOT2000	43 02	39	9 7	**11.7**	30	**20**	1 10
34	Muskoka	ON	A	4837	5	HOT2000	44 58	47	8	**11.7**	29	**20**	1 09
35	North Bay	ON	B	5318	5	HOT2000	46 37	49	5 9	**11.7**	28	**20**	1 05
36	Ottawa	ON	A	4673	5	HOT2000	45 45	46	8 9	11 4	31	23	1 00
37	Sault Ste Marie	ON	B	5180	5								
38	Simcoe	ON	A	3962	5	HOT2000	42 52	38	9 7	**11.7**	30	**20**	1 11
39	Sudbury	ON	B	5447	5	HOT2000	46 62	49	5 9	**11.7**	29	**20**	1 05
40	Thunder Bay	ON	B	5746	5								
41	Timmins	ON	B	6189	5								
42	Toronto	ON	A	4082	5	HOT2000	43 7	38 2	11 1	12 1	31	23	1 02
43	Windsor	ON	A	3590	5	HOT2000	42 27	37	10 3	**11.7**	31	**20**	1 15
43 1	user defined	ON			5								
Quebec													
44	Bagotville	QU	B	5776	6	HOT2000	48 33	52	5 7	**11**	28	**20**	0 98
45	Fort Chimo	QU	C	8460	6								
46	Montreal	QU	A	4471	6	HOT2000	45 47	44	6 4	10 5	30	23	1 00
47	Poste de la Baleine	QU	C	8225	6								
48	Quebec	QU	B	5080	6	HOT2000	46 8	46	7 4	10 5	28	22	1 02
49	Schefferville	QU	C	8229	6								
50	Sept Iles	QU	B	6135	6	HOT2000	50 22	51	6 5	**10.5**	24	**20**	0 96
51	Sherbrooke	QU	A	5242	6	HOT2000	45 43	49	8 7	**10.5**	29	**20**	1 02
52	Val-d'Or	QU	B	6146	6								

Residential Energy & Economic Simulator
WEATHER FILES

Tin design **21**

Database of monthly weather 11-Mar-94

Weather data for one city is selected into the OUTPUT range after entering the appropriate City number (see table below) in the INPUT sheet
The Output is available as a Lookup table (LOOKWX) for use by the Calc sheet
Weather is long-term data from HOT-2000 (ver 6 02); **Note that data for all cities has NOT been entered (see Table below)**

No.	City	Province	Zone	DD18	ProvNo	Source	Latitude	dTdesign (C)	TgrdS (C)	TgrdV (C)	Tcdbdes (C)	Zmet (m)	SolIndex
52 1	user defined	QU			6								
New Brunswick													
53	Chatham	NB	A	4884	7	HOT2000	47 02	45	7 6	**11.0**	30	**20**	1 04
54	Fredericton	NB	A	4699	7	HOT2000	45 92	45	7 7	11 9	29	21	0 98
55	Moncton	NB	A	4709	7	HOT2000	46 12	43	7 7	**11.0**	28	**20**	1 02
56	Saint John	NB	A	4771	7								
56 1	user defined	NB	A		7								
Nova Scotia													
57	Greenwood	NS	A	4130	8								
58	Halifax	NS	A	4123	8	HOT2000	44 7	37	8 5	11 0	26	20	0 94
59	Sydney	NS	A	4159	8								
60	Truro	NS	A	4704	8								
61	Yarmouth	NS	A	4024	8								
61 1	user defined	NS	A		8								
Prince Edward Island													
62	Charlottetown	PE	A	4623	9	HOT2000	46 25	41	7 5	10 1	26	21	0 96
63	Summerside	PE	A	4600	9								
63 1	user defined	PE	A		9								
Newfoundland													
64	Bonavista	NF	A	5010	10								
65	Gander	NF	A	5039	10	HOT2000	48 95	39	6 7	**10**	27	**20**	0 85
66	Goose Bay	NF	C	6522	10	HOT2000	53 32	52	4 9	10 3	27	**20**	0 89
67	Saint John's	NF	A	4804	10	HOT2000	47 52	35	6 7	8 5	24	20	0 76
68	Stephenville	NF	A	4783	10	HOT2000	48 53	38	6 7	**10**	24	**20**	0 89
68 1	user defined	NF			10								
Yukon Territory													
69	Whitehorse	YT	A	6879	11	HOT2000	60 72	62	2 0	14	25	15	0 82
69 1	user defined	YT			11								
69 2	user defined	YT			11								
Northwest Territories													
70	Baker Lake	NW	E	10870	12								
71	Fort Smith	NW	A	7852	12								
72	Frobisher Bay	NW	F	9845	12								
73	Inuvik	NW	C	10174	12								
74	Norman Wells	NW	C	8830	12								
75	Resolute	NW	H	12549	12								
76	Yellowknife	NW	B	8593	12	HOT2000	62 47	64	4 0	14	25	17	0 94
76 1	user defined	NW			12								

Summary of Base Houses:

Based on:

Archetypal houses generated from STARmod1.xls database — 21-Mar-94

(single detached houses only; bsmt temp. > 10C; ceiling area > 0)

Pollutant factors based on MatProp0.xls — 2-Apr-93

(operating energy uses provincial/regional elect. source breakdown;

embodied factors use X-Canada elect. source breakdown)

Housing statistics from Statistics Canada (Urban + Rural, single detached) — 1989

Simulations using HOT-2000, ver. 5.06 and long term weather; electric heat (other fuels use appropriate seasonal eff.)

Using space & water heating fuel split from database (local)

									Solar System	Space Heating	<<<<<< HRV >>>>>									
		No.houses in				Construction			MJ/y	%	(L/s)	(%)	C	C	C	C	m3	ac/h	ac/h	(kW/d)
Age	Region	sample	CanStatType	HouseType	ID	Date	Description	City	CSIA	SEff	VentRate	HRVeff	Tmain	Tbsmt	Tcrwl	Tswng	Volume	Nat_ach	Forc_ach	BaseLoad
<1921	BC	10	UrbanRural	Single	BC0020B	1909	Archetype - base case	Vancouver	0	82%	0	0%	18.3	15.3	15.0	3.5	478	0.70	0.00	15.0
1921-45	BC	22	UrbanRural	Single	BC2145B	1935	Archetype - base case	Vancouver	0	71%	0	0%	16.7	15.3	15.0	3.5	458	0.60	0.00	16.2
1946-60	BC	35	UrbanRural	Single	BC4660B	1954	Archetype - base case	Vancouver	0	75%	0	0%	18.1	15.8	15.0	3.5	441	0.53	0.00	17.6
1961-70	BC	29	UrbanRural	Single	BC6170B	1965	Archetype - base case	Vancouver	0	76%	0	0%	18.6	16.4	15.0	3.5	514	0.44	0.00	17.7
1971-80	BC	16	UrbanRural	Single	BC7180B	1974	Archetype - base case	Vancouver	0	79%	0	0%	18.0	16.1	15.0	3.5	553	0.39	0.00	18.5
>1981	BC	21	UrbanRural	Single	BC8189B	1988	Archetype - base case	Vancouver	0	73%	62	0%	20.9	19.8	15.0	3.3	687	0.21	0.32	14.3
<1921	PR	11	UrbanRural	Single	PR0020B	1912	Archetype - base case	Edmonton	0	70%	0	0%	19.7	16.0	15.0	3.5	407	0.54	0.00	15.1
1921-45	PR	16	UrbanRural	Single	PR2145B	1935	Archetype - base case	Edmonton	0	72%	0	0%	18.7	15.0	15.0	3.5	369	0.47	0.00	15.6
1946-60	PR	44	UrbanRural	Single	PR4660B	1953	Archetype - base case	Edmonton	0	73%	0	0%	19.2	15.6	15.0	3.5	417	0.31	0.00	15.9
1961-70	PR	49	UrbanRural	Single	PR6170B	1966	Archetype - base case	Edmonton	0	74%	0	0%	19.1	16.2	15.0	3.5	495	0.27	0.00	17.6
1971-80	PR	43	UrbanRural	Single	PR7180B	1975	Archetype - base case	Edmonton	0	76%	0	0%	18.9	16.2	15.0	3.5	485	0.20	0.00	17.5
>1981	PR	40	UrbanRural	Single	PR8189B	1989	Archetype - base case	Edmonton	0	67%	37	0%	21.0	20.0	15.3	3.5	593	0.22	0.23	14.0
<1921	ON	14	UrbanRural	Single	ON0020B	1903	Archetype - base case	Toronto	0	77%	0	0%	19.1	13.9	15.0	3.5	520	0.78	0.00	18.5
1921-45	ON	19	UrbanRural	Single	ON2145B	1934	Archetype - base case	Toronto	0	73%	0	0%	19.4	14.7	15.0	3.5	416	0.61	0.00	16.1
1946-60	ON	55	UrbanRural	Single	ON4660B	1956	Archetype - base case	Toronto	0	74%	0	0%	19.2	15.4	15.0	3.5	507	0.37	0.00	16.9
1961-70	ON	28	UrbanRural	Single	ON6170B	1965	Archetype - base case	Toronto	0	76%	0	0%	19.6	15.6	15.0	3.5	529	0.33	0.00	17.1
1971-80	ON	27	UrbanRural	Single	ON7180B	1974	Archetype - base case	Toronto	0	74%	0	0%	19.4	16.0	15.0	3.5	475	0.28	0.00	17.0
>1981	ON	42	UrbanRural	Single	ON8189B	1989	Archetype - base case	Toronto	0	69%	11	0%	21.0	20.0	15.0	3.5	847	0.19	0.04	14.0
<1921	QU	7	UrbanRural	Single	QU0020B	1891	Archetype - base case	Montreal	0	87%	0	0%	20.0	16.7	15.0	3.5	506	0.60	0.00	16.9
1921-45	QU	11	UrbanRural	Single	QU2145B	1937	Archetype - base case	Montreal	0	73%	0	0%	20.1	15.8	15.0	3.5	442	0.54	0.00	17.4
1946-60	QU	48	UrbanRural	Single	QU4660B	1954	Archetype - base case	Montreal	0	76%	0	0%	19.6	16.1	15.0	3.5	476	0.40	0.00	15.8
1961-70	QU	31	UrbanRural	Single	QU6170B	1966	Archetype - base case	Montreal	0	85%	0	0%	20.0	16.3	15.0	3.5	451	0.32	0.00	16.1
1971-80	QU	28	UrbanRural	Single	QU7180B	1974	Archetype - base case	Montreal	0	92%	0	0%	19.6	16.3	15.0	3.5	441	0.28	0.00	15.5
>1981	QU	38	UrbanRural	Single	QU8189B	1989	Archetype - base case	Montreal	0	100%	0	0%	20.9	19.9	15.0	3.5	471	0.15	0.00	14.0
<1921	MT	3	UrbanRural	Single	MT0020B	1892	Archetype - base case	Halifax	0	80%	0	0%	20.7	15.0	15.0	3.5	367	0.79	0.00	14.3
1921-45	MT	5	UrbanRural	Single	MT2145B	1940	Archetype - base case	Halifax	0	65%	0	0%	18.0	14.4	15.0	3.5	338	0.89	0.00	13.0
1946-60	MT	11	UrbanRural	Single	MT4660B	1955	Archetype - base case	Halifax	0	75%	0	0%	18.1	15.0	15.0	3.5	433	0.60	0.00	17.4
1961-70	MT	14	UrbanRural	Single	MT6170B	1965	Archetype - base case	Halifax	0	74%	0	0%	18.2	14.6	15.0	3.5	470	0.49	0.00	16.6
1971-80	MT	33	UrbanRural	Single	MT7180B	1975	Archetype - base case	Halifax	0	93%	0	0%	18.2	15.3	15.0	3.5	463	0.37	0.00	16.2
>1981	MT	15	UrbanRural	Single	MT8189B	1989	Archetype - base case	Halifax	0	99%	42	37%	21.0	19.5	15.0	3.5	625	0.17	0.27	15.1
Canada:																				
<1921																				
1921-45																				
1946-60																				
1961-70																				
1971-80																				
>1981																				
TOTAL		765																		

Summary of Base Houses:

												Slab Areas		Heated:			Unheated:		Bsmt	Shallow Bsmt. Areas	
		(kW/d)	L/d	(kWh/d)		cm2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2
Age	Region	Efans	Qdhw	Occ	ACH50	ELA	Asfc	Aclng	Awall	Adoor	Aoflr	Aslabper	Aslabctr	AhcsWall	Ahcsper	Ahcsctr	AuhcsWall	Auhcsflr	Aabvgrd	ASbgwall	ASflrper
<1921	BC	0.9	144	2.0	15	3,077	437.9	102.9	133.3	7.1	8.2	0.0	0.0	0.0	1.9	3.1	0.0	0.0	44.1	20.5	29.0
1921-45	BC	1.0	168	2.1	15	2,827	419.4	94.9	130.3	5.8	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5	19.4	23.5
1946-60	BC	1.0	189	2.2	13	2,396	456.7	106.4	127.5	6.2	34.3	0.7	1.4	0.0	0.0	0.0	0.0	0.0	43.4	19.7	22.1
1961-70	BC	0.9	205	2.3	11	2,357	498.7	115.4	129.4	5.4	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.1	20.7	22.7
1971-80	BC	1.0	198	2.3	10	2,171	521.4	116.2	143.3	6.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.2	24.0	24.4
>1981	BC	4.4	238	2.1	6	1,513	556.3	138.0	180.2	5.5	40.9	10.5	19.2	10.6	8.9	16.4	0.0	0.0	14.6	0.0	0.0
<1921	PR	2.0	174	2.2	8	1,359	379.9	82.8	129.8	5.3	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.9	10.4	15.0
1921-45	PR	1.6	142	1.9	8	1,203	361.1	76.2	126.7	4.4	14.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	18.3	6.9	6.1
1946-60	PR	1.5	177	2.1	7	1,052	394.4	87.7	118.5	4.4	7.7	1.9	1.4	0.0	0.4	0.6	0.0	0.0	27.3	4.6	4.2
1961-70	PR	1.6	188	2.2	6	1,107	445.3	103.4	117.2	4.3	2.0	0.7	1.3	0.0	0.0	0.0	0.0	0.0	29.9	2.2	2.0
1971-80	PR	1.2	200	2.3	5	812	466.7	106.5	126.3	4.2	12.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	26.4	3.8	3.6
>1981	PR	3.6	236	2.0	3	586	475.7	105.5	142.6	3.5	7.5	0.0	0.0	1.3	0.8	1.0	0.0	0.0	31.1	10.3	9.1
<1921	ON	2.2	189	2.3	11	2,432	473.7	89.9	204.6	5.4	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	16.4	14.0
1921-45	ON	1.6	168	2.1	12	1,906	387.3	80.0	139.5	4.7	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.4	16.7	15.6
1946-60	ON	1.3	168	2.1	9	1,822	475.7	111.7	135.0	5.2	10.1	4.7	4.4	0.0	0.0	0.0	0.0	0.0	26.2	7.2	6.2
1961-70	ON	1.2	212	2.4	9	1,685	488.5	114.3	144.7	4.4	18.2	0.9	1.1	0.0	0.0	0.0	0.0	0.0	25.2	6.0	4.7
1971-80	ON	1.0	202	2.3	8	1,407	462.8	110.7	130.9	3.2	27.0	4.9	2.3	0.0	0.0	0.0	0.0	0.0	37.8	20.5	18.2
>1981	ON	2.2	236	2.0	4	1,083	591.5	120.2	207.6	4.5	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.0	0.0
<1921	QU	0.8	206	2.4	9	1,918	438.6	93.7	161.3	3.5	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.1	5.1	3.9
1921-45	QU	1.7	238	2.5	10	1,775	424.4	91.3	148.5	4.1	17.9	4.2	0.0	0.0	0.0	0.0	0.0	0.0	24.4	15.2	13.9
1946-60	QU	1.1	181	2.2	8	1,412	433.8	97.3	133.0	6.1	4.8	1.6	0.3	0.0	0.5	0.4	0.0	0.0	32.4	16.1	14.1
1961-70	QU	0.7	214	2.4	7	1,195	433.1	99.5	117.5	7.7	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	12.3	11.3
1971-80	QU	0.3	202	2.4	6	1,036	422.4	95.9	113.0	6.1	8.5	1.0	1.3	0.0	0.0	0.0	0.0	0.0	39.5	12.3	10.8
>1981	QU	0.0	238	2.0	3	522	393.5	85.4	115.9	2.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	1.3	1.0
<1921	MT	1.9	145	2.0	14	2,103	369.7	77.2	147.9	2.4	37.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7	4.8	3.0
1921-45	MT	1.9	204	2.6	14	1,971	357.1	73.5	131.8	4.8	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0
1946-60	MT	1.7	199	2.4	11	1,887	434.2	97.4	131.7	4.9	25.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.6	9.7	11.9
1961-70	MT	1.5	209	2.5	9	1,687	425.2	100.9	112.2	4.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.2	13.7	15.1
1971-80	MT	0.5	219	2.5	7	1,293	438.4	104.1	117.8	4.4	9.0	0.5	1.1	0.0	0.0	0.0	0.0	0.0	38.2	22.0	19.3
>1981	MT	2.1	252	2.1	3	766	498.8	112.6	161.6	4.5	8.6	1.2	2.1	0.0	0.0	0.0	0.0	0.0	24.8	6.9	6.5
Canada:																					
<1921																					
1921-45																					
1946-60																					
1961-70																					
1971-80																					
>1981																					
TOTAL																					

Summary of Base Houses:

			Deep basement Areas (m2):				Windows:													Heated c/s	
		m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W
Age	Region	ASflrctr	AFbgUwall	AFbgLwall	AFflrper	AFflrctr	AWs	AWse	AWe	AWne	AWn	AWnw	AWw	AWsw	Floor_Area	Rclng	Rwall	Rdoor	Roflr	Rhcswall	Rhcsper
<1921	BC	49.5	2.8	4.8	4.3	9.7	4.0	0.0	5.4	0.0	3.8	0.0	3.2	0.0	183.8	1.88	1.27	0.47	0.91	0.00	0.00
1921-45	BC	33.2	6.8	11.1	10.1	16.3	5.0	0.0	4.6	0.0	3.4	0.0	4.5	0.0	176.0	3.05	1.45	0.40	1.39		
1946-60	BC	34.5	5.5	10.7	7.8	12.7	6.6	0.0	5.8	0.0	5.2	0.0	6.2	0.0	169.7	3.72	1.81	0.41	1.52		
1961-70	BC	36.2	10.0	18.3	15.1	27.8	7.1	0.0	5.6	0.0	5.5	0.0	7.3	0.0	197.6	3.41	1.97	0.45	2.31		
1971-80	BC	45.2	7.6	13.9	11.3	19.8	7.1	0.0	8.5	0.0	4.8	0.0	9.0	0.0	212.5	3.53	2.20	0.46	3.04		
>1981	BC	0.0	10.8	22.5	15.6	26.6	7.2	2.1	5.6	2.1	5.9	0.9	6.9	1.8	264.1	4.60	2.35	1.31	3.66	0.83	0.00
<1921	PR	14.7	12.6	22.5	18.4	26.3	2.2	0.0	2.8	0.0	3.5	0.0	3.8	0.0	156.5	3.38	2.06	0.59	1.58		
1921-45	PR	6.9	13.9	26.8	20.2	28.1	3.0	0.0	3.2	0.0	2.2	0.0	2.4	0.0	141.8	3.62	2.10	0.57	1.09		
1946-60	PR	6.1	18.1	29.5	26.7	40.6	2.8	0.0	3.8	0.0	2.9	0.0	3.7	0.0	160.3	3.98	1.98	0.60	1.20	0.00	0.40
1961-70	PR	3.2	23.6	45.1	35.6	59.3	4.0	0.0	4.1	0.0	4.1	0.0	3.3	0.0	190.5	3.24	2.12	0.58	1.33		
1971-80	PR	6.1	21.8	45.0	32.7	57.5	3.9	0.0	4.6	0.0	3.5	0.0	4.1	0.0	186.7	3.58	2.33	0.61	2.05		
>1981	PR	14.6	18.9	41.2	28.8	43.2	3.2	0.4	3.4	0.4	3.8	0.5	3.9	0.6	228.0	6.96	3.62	1.82	4.67	1.89	0.00
<1921	ON	18.7	9.8	17.0	14.3	23.2	5.2	0.0	4.1	0.0	3.4	0.0	3.8	0.0	200.1	3.37	1.43	0.54	0.85		
1921-45	ON	18.0	10.3	19.0	15.3	19.9	4.0	0.0	3.8	0.0	3.9	0.0	3.5	0.0	159.9	4.24	1.49	0.51	2.16		
1946-60	ON	7.2	20.1	37.2	30.2	51.6	4.5	0.0	4.9	0.0	4.1	0.0	5.1	0.0	195.1	4.11	1.71	0.51	1.84		
1961-70	ON	7.5	19.9	38.1	29.7	51.4	5.3	0.0	6.5	0.0	5.1	0.0	5.7	0.0	203.5	3.62	2.05	0.53	2.09		
1971-80	ON	26.5	9.0	16.2	13.3	22.6	3.9	0.0	5.7	0.0	3.7	0.0	6.3	0.0	182.7	3.98	2.21	0.55	2.54		
>1981	ON	0.0	26.8	62.7	41.7	69.6	6.7	0.8	5.8	0.8	6.0	1.3	4.8	0.6	325.9	5.69	2.55	1.84	5.23		
<1921	QU	4.9	19.3	32.0	28.7	45.2	2.6	0.0	2.8	0.0	4.0	0.0	3.1	0.0	194.5	2.94	2.72	0.48	0.82		
1921-45	QU	18.6	10.3	18.2	15.0	29.3	3.6	0.0	3.7	0.0	2.8	0.0	3.4	0.0	170.2	3.68	2.01	0.46	0.73		
1946-60	QU	23.0	12.9	22.6	19.2	32.5	4.1	0.0	3.8	0.0	3.9	0.0	4.7	0.0	183.0	4.23	1.96	0.48	1.72	0.00	0.00
1961-70	QU	18.4	15.2	27.4	22.7	40.6	4.8	0.0	4.5	0.0	4.1	0.0	4.9	0.0	173.6	3.67	2.28	0.48	2.11		
1971-80	QU	18.6	15.5	26.0	23.1	33.2	4.5	0.0	4.0	0.0	4.3	0.0	4.6	0.0	169.7	3.77	2.43	0.47	2.59		
>1981	QU	1.7	21.8	33.1	29.6	47.6	2.6	1.7	2.8	1.9	2.8	2.1	3.1	1.7	181.0	5.84	3.64	2.22	4.93		
<1921	MT	0.5	13.1	23.3	19.2	14.8	5.9	0.0	3.8	0.0	2.5	0.0	3.3	0.0	141.1	2.54	2.50	0.47	0.70		
1921-45	MT	0.0	14.8	22.6	20.6	27.5	2.5	0.0	3.9	0.0	2.6	0.0	2.7	0.0	130.1	1.73	2.08	0.51	0.85		
1946-60	MT	18.1	13.3	20.5	19.6	28.1	3.8	0.0	3.5	0.0	2.9	0.0	4.4	0.0	166.4	3.07	1.90	0.45	1.11		
1961-70	MT	23.4	14.3	20.0	21.6	37.5	3.9	0.0	4.3	0.0	4.3	0.0	3.3	0.0	180.6	2.89	1.79	0.49	3.01		
1971-80	MT	30.5	10.7	18.9	16.0	28.6	5.0	0.0	3.6	0.0	4.2	0.0	4.4	0.0	178.1	3.27	2.25	0.48	1.20		
>1981	MT	11.9	20.3	39.8	28.6	49.5	4.5	1.5	3.6	0.0	4.1	1.6	4.5	0.2	240.3	6.14	3.70	1.90	5.05		
Canada:																					
<1921																					
1921-45																					
1946-60																					
1961-70																					
1971-80																					
>1981																					
TOTAL																					

Summary of Base Houses:

						Slab RSI		Bsmt	Shallow basement			Deep basement RSI nominal:									
			Unheated c/s						Corrected R values												
		m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W	m2C/W
Age	Region	Rhcsctr	Ruhcswall	Ruhcsper	Ruhcsctr	Rslabper	Rslabctr	Rabvgrd	RSbgWall	RSflrper	RSflrctr	RFbgUWall	RFbgLWall	RFflrper	RFflrctr	RWs	RWse	RWe	RWne	RWn	RWnw
<1921	BC	0.00						0.91	0.58	0.00	0.00	0.23	0.23	0.00	0.00	0.26		0.25		0.26	
1921-45	BC							0.84	0.31	0.00	0.00	0.62	0.62	0.30	0.30	0.26		0.26		0.27	
1946-60	BC					0.00	0.00	1.13	0.75	0.00	0.00	0.47	0.47	0.27	0.27	0.28		0.27		0.29	
1961-70	BC							1.37	1.01	0.00	0.00	0.53	0.53	0.27	0.27	0.28		0.29		0.29	
1971-80	BC							1.35	0.37	0.00	0.00	0.36	0.36	0.26	0.26	0.29		0.30		0.29	
>1981	BC	0.00				0.59	0.40	1.17				1.14	1.14	0.05	0.05	0.36	0.36	0.36	0.36	0.36	0.36
<1921	PR							0.64	0.28	0.00	0.00	0.60	0.60	0.20	0.20	0.37		0.39		0.38	
1921-45	PR					0.00		0.56	0.26	0.00	0.00	0.42	0.42	0.23	0.23	0.36		0.35		0.36	
1946-60	PR	0.40				0.00	0.00	0.95	1.07	0.00	0.00	0.68	0.68	0.36	0.36	0.37		0.37		0.38	
1961-70	PR					0.00	0.00	0.95	0.55	0.00	0.00	0.75	0.75	0.33	0.33	0.35		0.37		0.36	
1971-80	PR					0.00		1.35	0.83	0.00	0.00	0.97	0.97	0.33	0.33	0.36		0.37		0.36	
>1981	PR	0.00						1.88	1.87	0.00	0.00	1.66	1.59	0.08	0.08	0.49	0.47	0.49	0.52	0.49	0.50
<1921	ON							0.65	0.41	0.00	0.00	0.33	0.33	0.20	0.20	0.35		0.36		0.37	
1921-45	ON							0.72	0.41	0.00	0.00	0.80	0.80	0.32	0.32	0.36		0.37		0.37	
1946-60	ON					0.00	0.00	0.75	0.69	0.00	0.00	0.56	0.56	0.28	0.28	0.37		0.37		0.37	
1961-70	ON					0.00	0.00	0.91	0.63	0.00	0.00	0.63	0.63	0.29	0.29	0.37		0.36		0.37	
1971-80	ON					0.00	0.00	1.35	0.80	0.00	0.00	0.66	0.66	0.28	0.28	0.35		0.34		0.38	
>1981	ON							1.44				1.47	0.04	0.00	0.00	0.36	0.36	0.36	0.36	0.36	0.36
<1921	QU							0.99	0.78	0.00	0.00	1.20	1.20	0.23	0.23	0.38		0.38		0.38	
1921-45	QU					0.00		0.90	0.66	0.00	0.00	0.57	0.57	0.23	0.23	0.38		0.38		0.38	
1946-60	QU	0.00				0.00	0.00	1.07	0.86	0.00	0.00	0.86	0.86	0.32	0.32	0.37		0.36		0.38	
1961-70	QU							1.31	1.27	0.00	0.00	1.18	1.18	0.42	0.42	0.37		0.39		0.37	
1971-80	QU					0.00	0.00	1.39	1.05	0.00	0.00	1.32	1.32	0.33	0.35	0.37		0.36		0.36	
>1981	QU							1.92	0.83	0.00	0.00	1.95	1.53	0.00	0.00	0.39	0.40	0.39	0.40	0.39	0.39
<1921	MT							1.19	0.26	0.00	0.00	0.96	0.96	0.12	0.12	0.33		0.33		0.35	
1921-45	MT							0.92				0.30	0.30	0.13	0.13	0.35		0.36		0.34	
1946-60	MT							0.82	0.91	0.00	0.00	0.59	0.59	0.21	0.21	0.35		0.35		0.39	
1961-70	MT							0.89	0.83	0.00	0.00	0.81	0.81	0.29	0.29	0.36		0.34		0.34	
1971-80	MT					0.00	0.00	1.33	1.15	0.00	0.00	0.92	0.92	0.38	0.38	0.35		0.33		0.34	
>1981	MT					1.76	1.76	2.50	2.52	0.00	0.00	1.65	1.16	0.18	0.18	0.37	0.38	0.37	0.38	0.37	0.38
Canada:																					
<1921																					
1921-45																					
1946-60																					
1961-70																					
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>1981																					
TOTAL																					

Summary of Base Houses:

					Unit Energy Demand					Unit Operating Energy Use by End use & Fuel Type											Unit Total
					<<<<<<<<<<<<<Space Heat >>>>>>>>>>>>				DHW	Utilities + Out		Space Heat					Water Heat				
		m2C/W	m2C/W	(W)	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y
Age	Region	RWw	RWsw	DesLoss	SpHtDmnd	IntGain	SolGain	TOTload	DHWload	ElectUtil	SpHtElect	SpHtOil	SpHtGas	SpHtWood	SpHtSolar	DHWElect	DHWOil	DHWGas	DHWWood	DHWSolar	Coal
<1921	BC	0.25		19,042	103.5	22.7	17.5	138.0	7.9	23.5	50.1	65.7	11.3	0.0	17.5	4.6	4.6	2.9	0.0	0.0	0.0
1921-45	BC	0.25		14,899	69.0	24.2	17.7	99.2	9.3	25.2	4.2	27.9	64.5	0.0	17.7	5.7	0.3	7.2	0.0	0.0	0.0
1946-60	BC	0.28		13,782	78.9	26.2	20.1	119.6	10.8	27.0	14.2	34.5	58.5	0.0	20.1	5.6	1.4	9.1	0.0	0.0	0.0
1961-70	BC	0.28		13,625	76.4	26.4	20.6	119.1	11.7	27.1	21.5	24.0	54.2	0.0	20.6	4.3	1.8	12.7	0.0	0.0	0.0
1971-80	BC	0.29		15,196	81.9	27.3	25.2	124.6	11.4	28.3	20.1	17.2	68.5	0.0	25.2	4.7	0.0	13.1	0.0	0.0	0.0
>1981	BC	0.36	0.36	11,578	89.2	27.0	22.3	136.9	13.3	27.2	18.5	0.0	106.5	0.0	22.3	2.2	0.0	20.9	0.0	0.0	0.0
<1921	PR	0.38		16,091	122.4	24.3	12.2	156.9	11.1	25.0	0.0	33.7	139.9	0.0	12.2	0.6	4.8	15.5	0.0	0.0	32.7
1921-45	PR	0.37		14,683	105.4	24.1	13.3	137.6	9.1	25.2	6.5	36.1	105.2	0.0	13.3	1.2	2.5	12.7	0.0	0.0	41.0
1946-60	PR	0.38		13,485	98.8	24.7	13.7	134.3	11.4	25.5	4.4	23.3	109.5	0.0	13.7	3.4	2.1	13.4	0.0	0.0	43.4
1961-70	PR	0.36		14,079	103.1	26.8	15.9	144.0	12.1	27.8	8.6	12.2	120.2	0.0	15.9	2.5	0.6	17.6	0.0	0.0	70.5
1971-80	PR	0.38		13,082	92.8	26.0	15.7	132.8	12.9	27.2	18.9	6.7	96.7	0.0	15.7	3.4	1.6	16.6	0.0	0.0	56.4
>1981	PR	0.49	0.46	13,468	112.3	25.8	15.1	153.2	15.2	25.8	0.0	0.0	168.3	0.0	15.1	0.0	0.0	28.2	0.0	0.0	37.1
<1921	ON	0.37		22,409	161.2	28.9	19.6	194.6	11.0	29.7	26.5	143.4	43.6	0.0	19.6	9.9	1.3	2.4	0.0	0.0	50.8
1921-45	ON	0.36		14,359	101.6	25.4	15.7	131.2	9.9	25.9	4.9	77.6	56.8	0.0	15.7	5.4	2.3	7.0	0.0	0.0	27.8
1946-60	ON	0.37		12,927	88.1	25.4	18.6	119.4	9.7	26.6	5.8	51.6	63.2	0.0	18.6	5.4	0.1	8.4	0.0	0.0	29.1
1961-70	ON	0.37		12,491	85.3	25.6	21.2	120.6	12.2	26.7	9.1	27.2	77.5	0.0	21.2	5.1	0.0	13.7	0.0	0.0	31.5
1971-80	ON	0.36		11,111	72.4	25.2	19.0	105.2	11.6	26.3	8.4	5.1	83.8	0.0	19.0	2.4	0.0	17.4	0.0	0.0	28.6
>1981	ON	0.36	0.36	12,744	103.9	23.7	20.4	148.0	13.5	23.9	0.0	0.0	150.4	0.0	20.4	0.0	0.0	24.9	0.0	0.0	18.4
<1921	QU	0.38		14,040	106.0	24.5	11.8	138.5	12.9	25.8	59.1	66.5	0.0	0.0	11.8	8.9	10.2	0.0	0.0	0.0	0.0
1921-45	QU	0.39		15,263	117.1	26.5	13.6	154.1	14.7	27.7	12.0	150.9	0.0	0.0	13.6	10.8	10.5	0.0	0.0	0.0	0.0
1946-60	QU	0.37		14,118	105.4	24.0	15.4	141.2	11.2	24.9	34.7	98.6	4.1	3.7	15.4	8.3	7.0	0.7	0.0	0.0	0.0
1961-70	QU	0.38		12,155	89.0	24.0	16.1	126.1	13.3	24.7	45.4	52.7	9.8	0.0	16.1	11.5	3.2	2.2	0.0	0.0	0.0
1971-80	QU	0.38		11,671	84.9	22.7	15.8	119.6	12.6	23.4	63.8	23.8	7.4	0.0	15.8	11.8	2.6	1.0	0.0	0.0	1.7
>1981	QU	0.39	0.39	7,420	54.0	21.2	13.9	88.6	14.8	21.1	54.0	0.0	0.0	0.0	13.9	15.9	0.0	0.0	0.0	0.0	0.0
<1921	MT	0.36		14,392	117.3	23.7	17.1	157.0	8.9	23.9	52.7	92.3	0.0	0.0	17.1	9.6	0.0	0.0	0.0	0.0	25.5
1921-45	MT	0.36		14,817	119.2	22.2	12.2	149.7	12.7	22.2	0.0	184.9	0.0	0.0	12.2	0.0	28.1	0.0	0.0	0.0	4.0
1946-60	MT	0.37		14,767	119.7	27.4	13.9	158.7	12.4	27.7	20.6	141.5	0.0	0.0	13.9	11.5	3.7	0.0	0.0	0.0	10.0
1961-70	MT	0.35		12,539	106.8	26.9	13.7	145.7	13.2	26.3	25.2	121.7	0.0	0.0	13.7	11.0	6.6	0.0	0.0	0.0	0.0
1971-80	MT	0.35		11,254	87.5	24.4	15.3	125.7	13.7	24.6	61.4	37.0	0.0	0.0	15.3	12.5	4.6	0.0	0.0	0.0	8.0
>1981	MT	0.37	0.37	9,407	76.2	24.8	15.9	116.8	15.5	25.2	77.5	0.0	0.0	0.0	15.9	16.6	0.0	0.0	0.0	0.0	132.4
Canada:																					
<1921																					
1921-45																					
1946-60																					
1961-70																					
1971-80																					
>1981																					
TOTAL																					

Summary of Base Houses:

		ource Operating Energy Use						Unit Emissions due to OPERATING energy: - including electrical generation split							1989 Housing Stock	Total Energy by End Use (TJ/year)					
		GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	GJ/y	kg/y	kg/y	kg/y	kg/y	kg/y	kg/y	kg/y		Utilities	Space Heat				Water Heat
Age	Region	Oil	Gas	Nuclear	Hydro	Other	TOTAL	CO2op	Particop	SOxop	COop	NOxop	VOCop	CH4op	Number	Electric	Electric	Oil	Gas	Wood	Electric
<1921	BC	71.6	35.7	0.0	76.9	5.7	190.0	7,548	1.5	9.0	0.2	59.1	0.3	0.1	30,145	708	1,510	1,981	341	0	138
1921-45	BC	28.7	81.4	0.0	34.6	2.6	147.3	6,389	1.1	3.7	0.2	27.7	0.2	0.1	107,100	2,702	448	2,992	6,911	0	609
1946-60	BC	36.6	80.4	0.0	46.1	3.4	166.6	6,997	1.2	4.7	0.2	33.8	0.3	0.1	186,710	5,049	2,645	6,439	10,918	0	1,053
1961-70	BC	26.7	81.5	0.0	52.1	3.9	164.1	6,364	1.2	3.9	0.2	25.9	0.3	0.1	133,505	3,621	2,866	3,207	7,236	0	579
1971-80	BC	18.0	96.2	0.0	52.2	3.9	170.3	6,463	1.3	3.0	0.2	19.9	0.3	0.1	211,649	5,982	4,249	3,637	14,499	0	994
>1981	BC	0.8	140.5	0.0	47.1	3.5	191.8	7,369	1.4	1.1	0.3	8.7	0.3	0.2	129,924	3,529	2,400	0	13,836	0	284
<1921	PR	38.5	159.8	0.0	15.2	0.7	247.0	13,661	4.6	31.9	3.3	48.5	0.3	0.2	110,948	2,770	0	3,741	15,520	0	70
1921-45	PR	38.6	121.5	0.0	20.6	0.9	222.7	12,504	5.2	38.9	4.0	48.4	0.3	0.2	168,504	4,238	1,095	6,090	17,727	0	207
1946-60	PR	25.4	129.3	0.0	19.3	0.9	218.4	12,133	5.4	39.7	4.2	38.9	0.3	0.2	294,130	7,501	1,307	6,850	32,201	0	1,003
1961-70	PR	12.7	148.8	0.0	14.3	1.3	247.8	14,573	8.2	61.5	6.7	36.7	0.3	0.2	186,788	5,188	1,608	2,273	22,457	0	467
1971-80	PR	8.3	120.5	0.0	32.4	1.3	218.8	11,603	6.6	49.0	5.3	27.9	0.3	0.2	275,851	7,504	5,213	1,847	26,679	0	951
>1981	PR	0.0	200.6	0.0	14.0	0.8	252.5	13,262	5.0	31.7	3.7	21.2	0.3	0.2	152,463	3,933	0	0	25,666	0	0
<1921	ON	146.8	48.7	32.1	20.0	0.4	298.8	17,593	6.3	59.6	5.0	131.7	0.3	0.1	293,520	8,716	7,781	42,079	12,790	0	2,898
1921-45	ON	81.1	65.3	17.6	11.0	0.2	203.0	11,609	3.7	32.7	2.8	75.0	0.2	0.1	244,171	6,314	1,203	18,954	13,864	0	1,317
1946-60	ON	52.9	73.2	18.4	11.5	0.2	185.3	10,052	3.7	31.0	2.9	53.2	0.2	0.1	523,527	13,919	3,040	27,016	33,089	0	2,850
1961-70	ON	28.5	92.9	19.9	12.4	0.3	185.4	9,453	3.9	30.6	3.1	35.3	0.2	0.1	291,760	7,781	2,663	7,922	22,617	0	1,498
1971-80	ON	6.3	102.7	18.0	11.3	0.2	167.1	8,064	3.6	25.8	2.8	17.5	0.2	0.1	318,531	8,392	2,683	1,623	26,683	0	769
>1981	ON	0.8	176.3	11.6	7.2	0.2	214.4	10,425	2.9	16.3	2.0	15.1	0.2	0.2	364,300	8,705	0	0	54,793	0	0
<1921	QU	80.0	0.0	3.3	99.7	0.0	182.9	5,848	0.5	10.3	0.2	61.9	0.1	0.0	127,881	3,300	7,564	8,500	0	0	1,140
1921-45	QU	163.2	0.0	1.8	53.6	0.0	218.5	11,928	1.0	17.8	0.3	129.4	0.2	0.0	92,711	2,564	1,113	13,992	0	0	1,001
1946-60	QU	108.0	4.8	2.4	72.1	3.7	191.0	8,134	0.7	12.6	0.2	85.2	0.1	0.0	235,390	5,863	8,160	23,218	959	879	1,955
1961-70	QU	58.8	11.9	2.8	86.7	0.0	160.3	4,895	0.5	7.9	0.1	45.9	0.1	0.0	185,087	4,573	8,411	9,762	1,808	0	2,120
1971-80	QU	38.0	8.4	5.1	99.9	0.3	153.4	3,384	0.7	13.1	0.2	23.9	0.1	0.0	227,748	5,328	14,533	5,415	1,690	0	2,686
>1981	QU	3.2	0.0	3.2	96.7	0.0	103.0	236	0.1	2.4	0.0	0.5	0.0	0.0	188,034	3,966	10,147	0	0	0	2,998
<1921	MT	217.0	0.0	27.4	12.9	4.4	287.2	18,600	6.3	126.5	2.7	100.5	0.7	0.2	104,486	2,494	5,502	9,643	0	0	999
1921-45	MT	234.0	0.0	4.2	11.3	0.7	254.2	17,536	2.2	41.2	0.8	174.8	0.3	0.1	71,687	1,592	0	13,257	0	0	0
1946-60	MT	199.0	0.0	10.8	32.3	1.7	253.9	15,632	3.2	64.5	1.3	127.4	0.4	0.1	116,284	3,224	2,398	16,452	0	0	1,342
1961-70	MT	139.8	0.0	0.0	65.4	0.0	205.2	10,231	1.0	21.9	0.3	104.5	0.2	0.0	77,904	2,052	1,960	9,480	0	0	856
1971-80	MT	93.8	0.0	8.6	79.0	1.4	190.7	7,729	2.3	51.0	0.9	43.7	0.3	0.1	123,055	3,026	7,557	4,551	0	0	1,542
>1981	MT	71.7	0.0	0.0	60.3	3.5	267.9	17,115	15.2	167.5	12.1	44.9	0.6	0.2	84,329	2,125	6,536	0	0	0	1,404
Canada:																					
<1921															666,980	17,988	22,357	65,944	28,651		5,246
1921-45															684,173	17,409	3,859	55,286	38,502		3,135
1946-60															1,356,041	35,556	17,551	79,976	77,167		8,202
1961-70															875,044	23,215	17,508	32,643	54,118		5,519
1971-80															1,156,834	30,231	34,235	17,075	69,551		6,941
>1981															919,050	22,257	19,084	0	94,295		4,686
TOTAL															5,658,122	146,657	114,594	250,923	362,284		33,729

Summary of Base Houses:

					Operating Energy Use by Source										Emissions due to OPERATING energy:						
					- at the house (TJ/year)				- including electrical generation split (TJ/year)						- including electrical generation split						
															CO2	Partic.	SOx	CO	NOx	VOC	CH4
Age	Region	Oil	Gas	Wood	Electric	Oil	Gas	Other	Coal	Oil	Gas	Nuclear	Hydro	Other	(tonne/year)	(tonne/year)	(tonne/year)	(tonne/year)	(tonne/year)	(tonne/year)	(tonne/year)
<1921	BC	140	89	0	2,356	2,121	429	0	0	2,158	1,076	0	2,319	173	227,523	45.9	270.3	6.7	1,780.8	10.2	2.8
1921-45	BC	27	774	0	3,759	3,019	7,685	0	0	3,079	8,717	0	3,701	276	684,240	113.0	395.5	24.0	2,962.3	22.9	11.5
1946-60	BC	254	1,701	0	8,747	6,694	12,619	0	0	6,833	15,018	0	8,611	642	1,306,356	229.3	885.5	44.7	6,317.8	47.8	21.4
1961-70	BC	243	1,700	0	7,066	3,450	8,936	0	0	3,562	10,874	0	6,956	518	849,688	166.0	515.4	29.7	3,463.4	35.4	15.7
1971-80	BC	0	2,773	0	11,225	3,637	17,271	0	0	3,816	20,351	0	11,050	824	1,367,975	271.0	631.4	49.6	4,209.3	57.5	27.7
>1981	BC	0	2,714	0	6,213	0	16,550	0	0	99	18,254	0	6,116	456	957,417	179.9	145.5	37.4	1,131.6	36.8	22.0
								B.C. Subtotal:	**0**	**19,548**	**74,290**	**0**	**38,754**	**2,888**	**5,393,198**	**1,005**	**2,844**	**192**	**19,865**	**211**	**101**
<1921	PR	528	1,718	0	2,841	4,269	17,239	0	3,633	4,270	17,729	0	1,689	79	1,515,637	507.1	3,539.4	371.1	5,376.3	30.6	20.9
1921-45	PR	419	2,137	0	5,541	6,510	19,864	0	6,900	6,511	20,479	0	3,478	160	2,107,006	875.9	6,557.4	675.2	8,154.8	43.7	26.2
1946-60	PR	614	3,949	0	9,810	7,464	36,150	0	12,770	7,467	38,033	0	5,687	270	3,568,608	1,590.6	11,664.8	1,240.7	11,431.2	75.5	47.8
1961-70	PR	105	3,297	0	7,263	2,378	25,754	0	13,177	2,381	27,803	0	2,665	252	2,722,017	1,536.7	11,487.7	1,246.7	6,859.3	60.0	36.8
1971-80	PR	436	4,572	0	13,668	2,283	31,251	0	15,553	2,286	33,239	0	8,936	352	3,200,642	1,821.3	13,513.2	1,471.3	7,706.0	73.0	44.2
>1981	PR	0	4,301	0	3,933	0	29,967	0	5,659	1	30,577	0	2,139	123	2,021,920	767.8	4,835.1	570.7	3,229.4	44.0	34.4
								Prairies Subtotal:	**57,693**	**22,915**	**167,859**	**0**	**24,594**	**1,236**	**15,135,830**	**7,099**	**51,598**	**5,576**	**42,757**	**327**	**210**
<1921	ON	379	696	0	19,395	42,458	13,486	0	14,910	43,076	14,291	9,412	5,883	124	5,163,966	1,862.4	17,495.0	1,456.8	38,646.1	85.9	30.1
1921-45	ON	571	1,713	0	8,833	19,525	15,577	0	6,791	19,807	15,943	4,286	2,679	56	2,834,515	905.9	7,989.0	682.7	18,308.1	48.8	23.2
1946-60	ON	68	4,393	0	19,809	27,084	37,482	0	15,228	27,716	38,304	9,612	6,009	126	5,262,426	1,946.7	16,212.6	1,502.7	27,846.0	95.2	51.9
1961-70	ON	0	4,001	0	11,941	7,922	26,618	0	9,180	8,303	27,113	5,795	3,622	76	2,757,876	1,147.2	8,917.0	897.1	10,299.7	53.0	34.0
1971-80	ON	0	5,532	0	11,844	1,623	32,215	0	9,105	2,001	32,706	5,748	3,593	76	2,568,659	1,135.4	8,209.8	889.0	5,571.6	52.1	38.5
>1981	ON	0	9,067	0	8,705	0	63,860	0	6,692	278	64,221	4,224	2,640	56	3,797,701	1,068.4	5,919.9	731.3	5,511.1	77.3	68.3
								Ontario Subtotal:	**61,905**	**101,181**	**192,577**	**39,077**	**24,427**	**514**	**22,385,144**	**8,066**	**64,743**	**6,160**	**106,183**	**412**	**246**
<1921	QU	1,304	0	0	12,004	9,805	0	0	0	10,226	0	417	12,751	0	747,888	67.3	1,320.2	20.5	7,911.1	11.1	2.0
1921-45	QU	970	0	0	4,677	14,962	0	0	0	15,126	0	162	4,968	0	1,105,865	93.1	1,650.9	30.3	11,995.8	15.5	2.6
1946-60	QU	1,642	164	0	15,978	24,860	1,123	879	0	25,421	1,123	555	16,972	879	1,914,590	167.1	2,962.1	53.1	20,044.3	27.7	5.7
1961-70	QU	594	399	0	15,105	10,356	2,206	0	0	10,886	2,206	525	16,045	0	905,909	86.0	1,459.6	26.2	8,500.0	14.2	4.4
1971-80	QU	584	219	0	22,546	5,999	1,909	0	392	8,660	1,909	1,158	22,742	68	770,668	150.0	2,977.7	56.6	5,441.7	19.2	6.3
>1981	QU	0	0	0	17,111	0	0	0	0	600	0	594	18,176	0	44,429	12.0	456.3	1.2	96.1	1.8	0.6
								Quebec Subtotal:	**392**	**70,920**	**5,238**	**3,411**	**91,655**	**947**	**5,489,350**	**575**	**10,827**	**188**	**53,989**	**89**	**21**
<1921	MT	0	0	0	8,995	9,643	0	0	2,669	22,670	0	2,860	1,349	459	1,943,419	654.1	13,219.4	286.2	10,504.9	71.1	19.6
1921-45	MT	2,016	0	0	1,592	15,273	0	0	284	16,778	0	305	807	49	1,257,076	157.5	2,950.5	59.2	12,534.4	22.2	4.5
1946-60	MT	428	0	0	6,965	16,880	0	0	1,169	23,144	0	1,252	3,757	201	1,817,713	373.6	7,505.5	151.8	14,815.5	45.5	11.2
1961-70	MT	512	0	0	4,867	9,992	0	0	0	10,893	0	0	5,095	0	797,058	78.0	1,703.6	21.8	8,137.7	12.7	2.5
1971-80	MT	562	0	0	12,125	5,113	0	0	984	11,546	0	1,054	9,716	169	951,042	283.1	6,271.8	111.9	5,380.2	32.7	9.1
>1981	MT	0	0	0	10,065	0	0	0	11,164	6,044	0	0	5,085	299	1,443,290	1,282.1	14,126.8	1,017.3	3,783.5	46.8	14.0
Canada:								Maritimes Subtotal:	**16,270**	**91,075**	**0**	**5,471**	**25,809**	**1,177**	**8,209,598**	**2,828**	**45,778**	**1,648**	**55,156**	**231**	**61**
<1921		2,351	2,503		45,592	68,295	31,155		21,212	82,400	33,095	12,688	23,992	834	9,598,433	3,137	35,844	2,141	64,219	209	75
1921-45		4,003	4,624		24,403	59,288	43,125		13,975	61,300	45,138	4,754	15,634	541	7,988,702	2,145	19,543	1,471	53,955	153	68
1946-60		3,006	10,207		61,309	82,982	87,374		29,166	90,581	92,477	11,420	41,036	2,119	13,869,695	4,307	39,230	2,993	80,455	292	138
1961-70		1,455	9,396		46,243	34,099	63,514		22,357	36,025	67,996	6,319	34,382	846	8,032,547	3,014	24,083	2,221	37,260	175	93
1971-80		1,582	13,095		71,408	18,656	82,646		26,035	28,310	88,205	7,960	56,037	1,488	8,858,986	3,661	31,604	2,578	28,309	234	126
>1981		0	16,082		46,027	0	110,377		23,515	7,022	113,051	4,818	34,157	933	8,264,757	3,310	25,484	2,358	13,752	207	139
TOTAL		12,397	55,907		294,981	263,320	418,191	0	136,260	305,639	439,964	47,959	205,239	6,761	56,613,119	19,574	175,789	13,763	277,950	1,270	640

Appendix C.1 REES Results

Results for the following runs are included (see Tables 5.7 to 5.9 for a summary of results):

Run	Run ID	Retrofit Level	Minimize impact on[1].	Cost Criteria[2] ($/GJ eff)	Ventilation Control	Summer Fans	Remarks
1	H99C01	HIGH	Cost	unlimited	optimum	off	
2	**H12C01**	HIGH	Cost	$12.00	optimum	off	< see Tables 5.3 to 5.6
3	H12C02	HIGH	Cost	$12.00	continuous	off	
5	M12C01	MID	Cost	$12.00	optimum	off	
6	L12C01	LOW	Cost	$12.00	optimum	off	

[1] *minimize environmental impact* meant that cellulose insulation was used in wall retrofits and, for HIGH level retrofits, that a solar domestic water heater was used *Minimize cost* meant that fiberglass insulation was used in wall retrofits, wherever technically feasible .

[2] Retrofit houses only if the life-cycle effective retrofit energy cost less than value shown.
Effective cost = (Retrofit cost)/(Present Worth Factor x Annual Source Energy Savings - Source Retrofit Embodied Energy)

For each run, the following are included:

- Projections to the year 2030
- House envelope descriptive tables (2 pages)
- Retrofit results - tables and graphs; energy and pollutant reduction due to operation, embodied pollutants and energy, retrofit costs (2 pages)
- Normalized total house energy

Canadian Single Detached Residential Retrofit Program

Run ID: **H99C01**

Assumptions:

Description: **Description:**

Retrofit Goal: **HIGH** (Increase 30% over MID)

Impact: **minimize Cost**

	Main floor	Basement
Interior finish:	**strip**	**strip**
Exterior finish:	**strip**	**retain**
Water consumption:	**20%**	reduction
Utilities consumption:	**20%**	reduction*

*(except with combustion heating & hydroelectric utilities)

Mechanical systems:	
Space heating:	**upgrade**
Domestic hot water:	**upgrade**
Ventilation control:	**iaq_opt**
	no ventilation in summer

Amortization period: **30** years

Present Worth Factor: **18.0**

Retrofit if less than: **$999.00** /GJ equiv

(energy retrofit cost/life-cycle net energy)

Max. Exterior wall (urban)

3.00 RSI added

Canadian Single Detached Housing Projections: Demolition rate = 8.1% of new housing

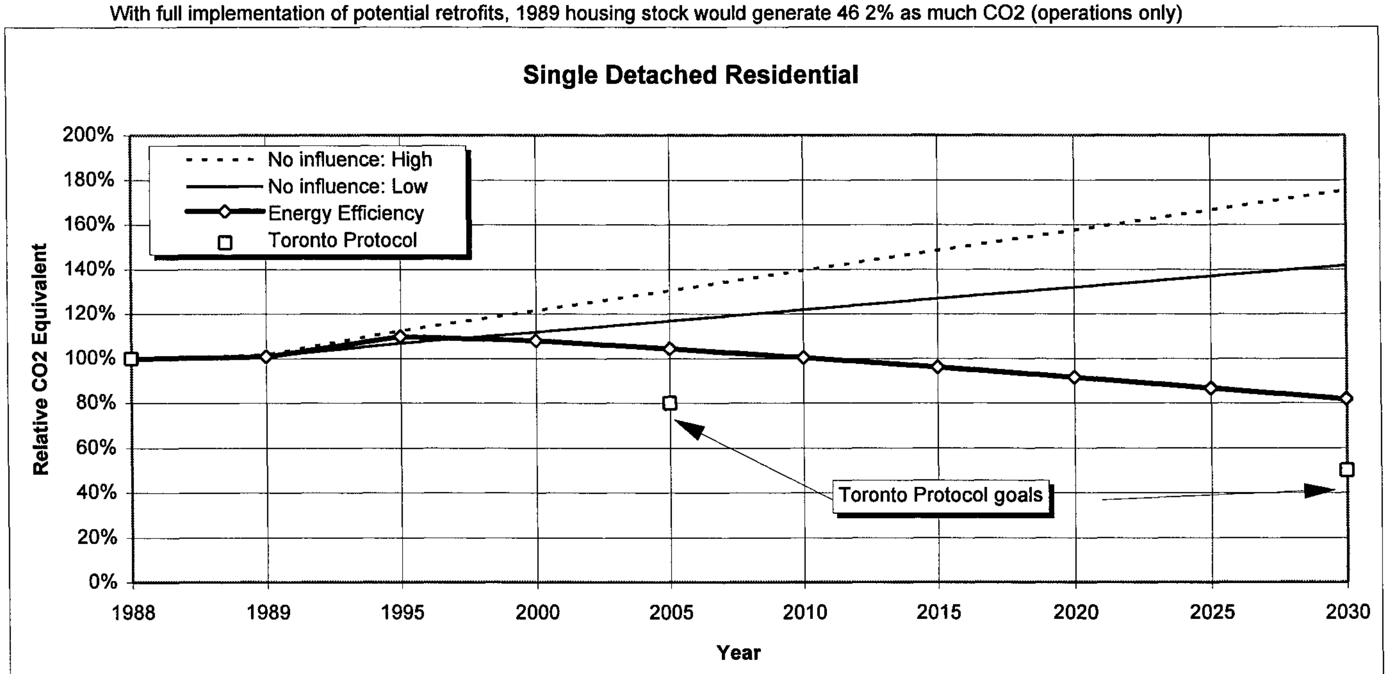
New housing are all houses built after 1989; Old housing are not retrofitted pre-1989; Retrofits are accumulated totals to date.

Year	1989	1995	2000	2005	2010	2015	2020	2025	2030
Old housing	5,658,122	5,612,310	4,809,225	4,008,016	3,208,028	2,408,733	1,609,571	810,416	11,218
Retrofits	0	0	770,623	1,541,508	2,312,553	3,083,674	3,854,782	4,625,853	5,396,877
New Housing	0	545,032	927,472	1,281,787	1,616,794	1,939,932	2,258,948	2,576,003	2,892,128
Total Housing	5,658,122	6,157,342	6,507,320	6,831,311	7,137,375	7,432,339	7,723,301	8,012,272	8,300,223
New Housing energy use and pollutant generation based on 1989 housing values, multiplied by:									
Relative to 1989:	100%	90%	81%	73%	66%	59%	53%	48%	43%

Results:

100 0% of original (1989) housing stock had potential for retrofit, however only 95 4%of original stock were actually retrofitted

With full implementation of potential retrofits, 1989 housing stock would generate 46 2% as much CO2 (operations only)



Year	Energy Efficiency Option: Energy Retrofit Costs ($ 10^6/yr)	Total energy (source) (%)	Pollutant Generation due to Operation & Retrofits: CO2 (%)	CO (%)	NOx (%)	CH4 (%)	CO2 Equivalent (%)	Toronto Protocol Goals (%)	No Influence Options: Low est. CO2 Equivalent (%)	High est. CO2 Equivalent (%)
1988	0	100%	100%	100%	100%	100%	100%	**100%**	100%	100%
1989	0	101%	101%	101%	101%	101%	101%		101%	102%
1995	0	116%	109%	117%	104%	115%	110%		107%	113%
2000	1,954	113%	107%	122%	96%	115%	108%		112%	122%
2005	1,954	**110%**	103%	124%	88%	113%	**104%**	**80%**	**117%**	**131%**
2010	1,955	106%	98%	125%	79%	111%	100%		122%	140%
2015	1,955	102%	93%	126%	71%	107%	96%		127%	149%
2020	1,955	98%	88%	126%	62%	104%	92%		132%	158%
2025	1,955	93%	83%	126%	53%	100%	87%		137%	167%
2030	1,955	**88%**	**77%**	**126%**	**44%**	**96%**	**82%**	**50%**	**142%**	**176%**
2030		50%	45.1%	86%	33%	47%	**54%**	< Existing housing stock only		

Note: Energy Efficiency Option values calculated on basis of 1989 values, then adjusted by estimated increases from 1988 to 1989

Retrofit of Canadian Houses: HIGH Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$999.00** /GJ equiv

Run ID: H99C01

Base

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:

Space heating: upgrade

Domestic hot water: upgrade

Ventilation control: iaq_opt

Operations:

DHW: 20% reduction

Utilities: 20% reduction

Region	Age	Number of Houses Retrofitted	Volume (m^3)	Floor area (incl bsmt) (m^2)	Natural air change Base ac/h	Natural air change Upgrade ac/h	Total air change Base ac/h	Total air change Upgrade ac/h	Ventilation more than 0.4 ac/h	Interior retrofits: Ventilation less than 0.25 ac/h**	Interior retrofits: % of stock	Walls Base RSI	Walls Upgrade RSI
B C	<1921	10	478	180	0 70	0 32	0 70	0 34	10%	0%	0%	1 27	3 23
	1921-45	22	458	172	0 60	0 31	0 60	0 34	9%	0%	0%	1 45	3 26
	1946-60	35	441	166	0 53	0 31	0 53	0 33	9%	0%	0%	1 81	3 25
	1961-70	29	514	194	0 44	0 27	0 44	0 30	3%	0%	0%	1 97	3 26
	1971-80	16	553	208	0 39	0 26	0 39	0 30	6%	0%	0%	2 20	3 33
	>1981	21	687	263	0 21	0 18	0 53	0 25	0%	0%	0%	2 35	3 30
Prairies	<1921	11	407	150	0 54	0 21	0 54	0 29	0%	0%	9%	2 06	3 64
	1921-45	16	369	136	0 47	0 19	0 47	0 28	0%	0%	13%	2 10	4.13
	1946-60	44	417	154	0 31	0 18	0 31	0 28	2%	0%	9%	1 98	3 77
	1961-70	49	495	184	0 27	0 16	0 27	0 27	0%	0%	10%	2 12	3 82
	1971-80	43	485	182	0 20	0 14	0 20	0 27	0%	0%	5%	2 33	3 98
	>1981	40	593	226	0 22	0 13	0 44	0 26	0%	0%	0%	3 62	3 64
Ontario	<1921	14	520	186	0 78	0 37	0 78	0 40	50%	0%	100%	1 43	3 23
	1921-45	19	416	150	0 61	0 30	0 61	0 34	5%	0%	100%	1 49	3 19
	1946-60	55	507	190	0 37	0 22	0 37	0 28	2%	0%	0%	1 71	3 31
	1961-70	28	529	199	0 33	0 20	0 33	0 27	0%	0%	0%	2 05	3 75
	1971-80	27	475	178	0 28	0 19	0 28	0 27	0%	0%	4%	2 21	3 64
	>1981	42	847	324	0 19	0 16	0 24	0 26	0%	0%	0%	2 55	3 31
Quebec	<1921	7	506	189	0 60	0 21	0 60	0 28	0%	0%	14%	2 72	6 17
	1921-45	11	442	163	0 54	0 20	0 54	0 29	9%	0%	18%	2 01	6 51
	1946-60	48	476	173	0 40	0 18	0 40	0 28	4%	0%	33%	1 96	6 17
	1961-70	31	451	166	0 32	0 17	0 32	0 27	0%	0%	32%	2 28	6 07
	1971-80	28	441	163	0 28	0 16	0 28	0 27	0%	0%	25%	2 43	6 40
	>1981	38	471	180	0 15	0 14	0 15	0 26	0%	0%	0%	3 64	4 71
Maritimes	<1921	3	367	138	0 79	0 35	0 79	0 36	33%	0%	0%	2 50	3 60
	1921-45	5	338	127	0 89	0 34	0 89	0 36	40%	0%	0%	2 08	4 84
	1946-60	11	433	157	0 60	0 26	0 60	0 31	18%	0%	27%	1 90	5 66
	1961-70	14	470	166	0 49	0 23	0 49	0 30	0%	0%	57%	1 79	6 12
	1971-80	33	463	172	0 37	0 20	0 37	0 27	0%	0%	15%	2 25	5 75
	>1981	15	625	238	0 17	0 16	0 44	0 25	0%	0%	0%	3 70	4 73
CANADA	<1921	45	455	169	0 68	0 29	0 68	0 33	28%	0%	48%	2 00	3 97
	1921-45	73	405	150	0 62	0 27	0 62	0 32	9%	0%	41%	1 83	4 38
	1946-60	193	455	168	0 44	0 23	0 44	0 30	5%	0%	10%	1 87	4 43
	1961-70	151	492	182	0 37	0 21	0 37	0 28	1%	0%	14%	2 04	4 60
	1971-80	147	483	181	0 30	0 19	0 30	0 27	1%	0%	9%	2 28	4 62
	>1981	156	644	246	0 19	0 15	0 36	0 26	0%	0%	0%	3 17	3 94
	Total:	**765**											
	Average:*		489	183	0 43	0 22	0 46	0 29	6%	0%	17%	2 20	4 32

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Retrofit of Canadian Houses: HIGH Scenario

Cutoff for retrofit: **$999.00** /GJ equiv

Base

Region	Age	Ceiling Base RSI	Ceiling Upgrade RSI	Above grade Bsmt Base RSI	Above grade Bsmt Upgrade RSI	Windows (south) Base RSI	Windows (south) Upgrade RSI	Window /floor area %	Energy Related Costs: Retrofit Unit Cost $	Energy Related Costs: Total Cost (10^6 $)	Life cycle Unit Energy Cost ($/GJ/30y)
B C	<1921	1 88	9 41	0 91	3 35	0 26	0 42	9%	14,390	434	8 43
	1921-45	3 05	8 28	0 84	3 07	0 26	0 39	10%	13,596	1,456	12 01
	1946-60	3 72	8 64	1 13	2 92	0 28	0 39	14%	14,225	2,656	11 41
	1961-70	3 41	8 68	1 37	2 85	0 28	0 41	13%	13,615	1,818	11 06
	1971-80	3 53	8 78	1 35	2 78	0 29	0 41	14%	14,197	3,005	12 86
	>1981	4 60	8 11	1 17	2 77	0 36	0 37	12%	11,474	1,491	7 78
									Subtotal:	**10,859**	
Prairies	<1921	3 38	9 41	0 64	3 39	0 37	0 66	8%	12,673	1,406	5 63
	1921-45	3 62	9 51	0 56	3 44	0 36	0 59	8%	12,756	2,150	6 77
	1946-60	3 98	9 21	0 95	3 12	0 37	0 60	8%	12,422	3,654	7 86
	1961-70	3 24	8 64	0 95	2 96	0 35	0 55	8%	12,436	2,323	7 63
	1971-80	3 58	8 94	1 35	2 77	0 36	0 59	9%	12,952	3,573	9 82
	>1981	6 96	8 32	1 88	2 85	0 49	0 62	7%	6,708	1,023	4 10
									Subtotal:	**14,128**	
Ontario	<1921	3 37	9 47	0 65	3 52	0 35	0 48	9%	14,117	4,144	4 85
	1921-45	4 24	8 97	0 72	3 30	0 36	0 48	10%	11,527	2,815	6 38
	1946-60	4 11	8 65	0 75	3 20	0 37	0 47	10%	12,927	6,768	9 17
	1961-70	3 62	8 52	0 91	3 02	0 37	0 48	11%	13,695	3,996	9 96
	1971-80	3 98	7 95	1 35	2 71	0 35	0 48	11%	12,545	3,996	10 65
	>1981	5 69	7 54	1 44	2 45	0 36	0 49	8%	10,684	3,892	7 23
									Subtotal:	**25,610**	
Quebec	<1921	2 94	11 70	0 99	3 11	0 38	0 47	7%	14,202	1,816	8 12
	1921-45	3 68	11 70	0 90	3 49	0 38	0 48	8%	16,005	1,484	6 93
	1946-60	4 23	11 70	1 07	3 19	0 37	0 47	10%	14,533	3,421	8 03
	1961-70	3 67	11 70	1 31	2 83	0 37	0 48	11%	13,672	2,531	10 67
	1971-80	3 77	11 62	1 39	2 77	0 37	0 48	11%	13,201	3,007	11 83
	>1981	5 84	11 70	1 92	2 24	0 39	0 48	10%	8,426	1,584	27 96
									Subtotal:	**13,842**	
Maritimes	<1921	2 54	9 36	1 19	2 95	0 33	0 47	11%	11,382	1,189	5 20
	1921-45	1 73	10 30	0 92	3 39	0 35	0 49	9%	14,112	1,012	5 51
	1946-60	3 07	11 06	0 82	3 42	0 35	0 48	9%	14,228	1,654	5 61
	1961-70	2 89	11 53	0 89	3 30	0 36	0 49	9%	13,798	1,075	6 77
	1971-80	3 27	11 20	1 33	2 97	0 35	0 50	10%	13,644	1,679	9 34
	>1981	6 14	11 70	2 50	3 10	0 37	0 52	8%	8,625	727	8 04
									Subtotal:	**7,337**	
CANADA	<1921	2 82	9 87	0 88	3 26	0 34	0 50	9%	13,353	8,989	6 45
	1921-45	3 26	9 75	0 79	3 34	0 34	0 48	9%	13,599	8,916	7 52
	1946-60	3 82	9 85	0 95	3 17	0 35	0 48	10%	13,667	18,153	8 42
	1961-70	3 36	9 81	1 08	2 99	0 35	0 48	11%	13,443	11,741	9 22
	1971-80	3 62	9 70	1 35	2 80	0 34	0 49	11%	13,308	15,259	10 90
	>1981	5 85	9 47	1 78	2 68	0 39	0 50	9%	9,183	8,717	11 02
	Total:								**Total:**	**71,775**	
	Average:	3 79	9 74	1 14	3 04	0 35	0 49	10%	**$12,759** (unweighted)		8 92

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Retrofit of Canadian Houses: HIGH Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Retrofit rules: HIGH scenario (Increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

Min. upgrade:	RSI	
Walls	0 50	added
Windows	0 10	added

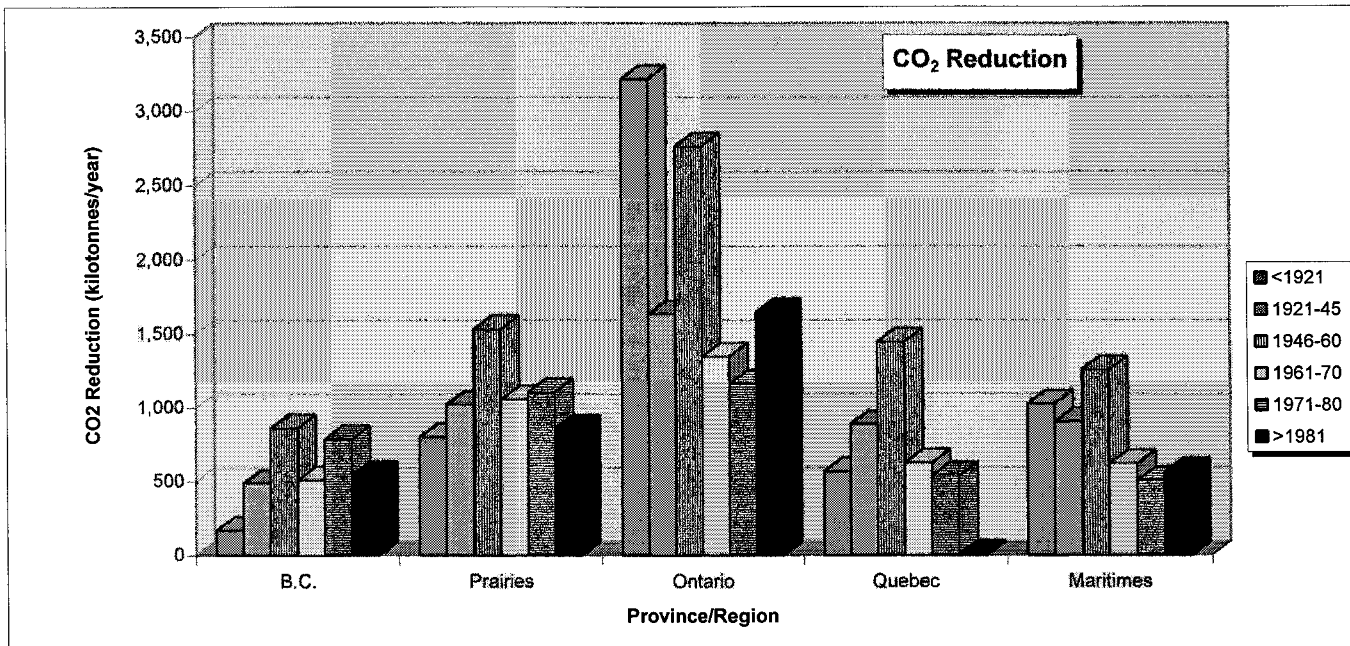
Mechanical systems:

Space heating:	upgrade	Ventilation control: iaq_opt
Domestic hot water:	upgrade	no ventilation in summer

Cutoff for retrofit: **$999.00** /GJ equiv
Run ID: H99C01
Base

Max. Exterior (urban): 3 00 RSI added

Age	Housing Stock	CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada (kilotonnes/yr)	CO_2 Reduction	CH4 Reduction (kilotonnes/yr)	CO Reduction (kilotonnes/yr)	NOx Reduction (kilotonnes/yr)
		(kilotonnes/yr)									
<1921	666,980	170	801	3,218	569	1,026	**5,785**	60%	0.04	0.54	45.2
1921-45	684,173	488	1,023	1,638	888	902	**4,939**	62%	0.04	0.10	39.7
1946-60	1,356,041	860	1,534	2,761	1,446	1,257	**7,859**	57%	0.07	0.29	55.4
1961-70	875,044	511	1,057	1,349	625	620	**4,161**	52%	0.05	0.31	23.5
1971-80	1,156,834	785	1,106	1,161	537	505	**4,095**	46%	0.06	0.37	15.0
>1981	919,050	543	859	1,648	10	562	**3,622**	44%	0.07	0.39	4 9
Total	5,658,122	3,357	6,380	11,775	4,076	4,873	**30,460**	**54%**	0.33	2.01	183.6



Age	Housing Stock	RETROFIT EMBODIED: POLLUTANTS CO_2 (kilotonnes)	payback (years)	CH4 (kilotonnes)	payback (years)	CO (kilotonnes)	payback (years)	NOx (kilotonnes)	payback (years)	RETROFIT ENERGY Used (PJ)	Payback (years)
<1921	666,980	1,749	0.3	0.04	0.9	2.3	4.3	4.9	0.1	45.2	0.5
1921-45	684,173	1,656	0.3	0.03	0.9	2.4	23.3	4.6	0.1	42.1	0.5
1946-60	1,356,041	3,523	0.4	0.07	1.0	4.3	14.6	9.3	0.2	91.8	0.7
1961-70	875,044	2,338	0.6	0.05	1.0	2.7	8.6	6.3	0.3	61.4	0.8
1971-80	1,156,834	3,116	0.8	0.07	1.1	3.3	8.9	8.3	0.6	82.0	0.9
>1981	919,050	2,099	0 6	0 04	0 6	2 4	6 1	5 3	1.1	58 6	0 8
Total	5,658,122	14,480	0.5	0.30	0.9	17.4	8.6	38.6	0.2	381	0.7

Retrofit of Canadian Houses: HIGH Scenario

Simulations using REES version 1 20

Cutoff for retrofit: **$999.00** /GJ equiv

Run ID: H99C01

Base

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls — 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) — 1989

Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

Retrofit rules: HIGH scenario (Increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Min. upgrade:	RSI
Walls	0 50
Windows	0 10

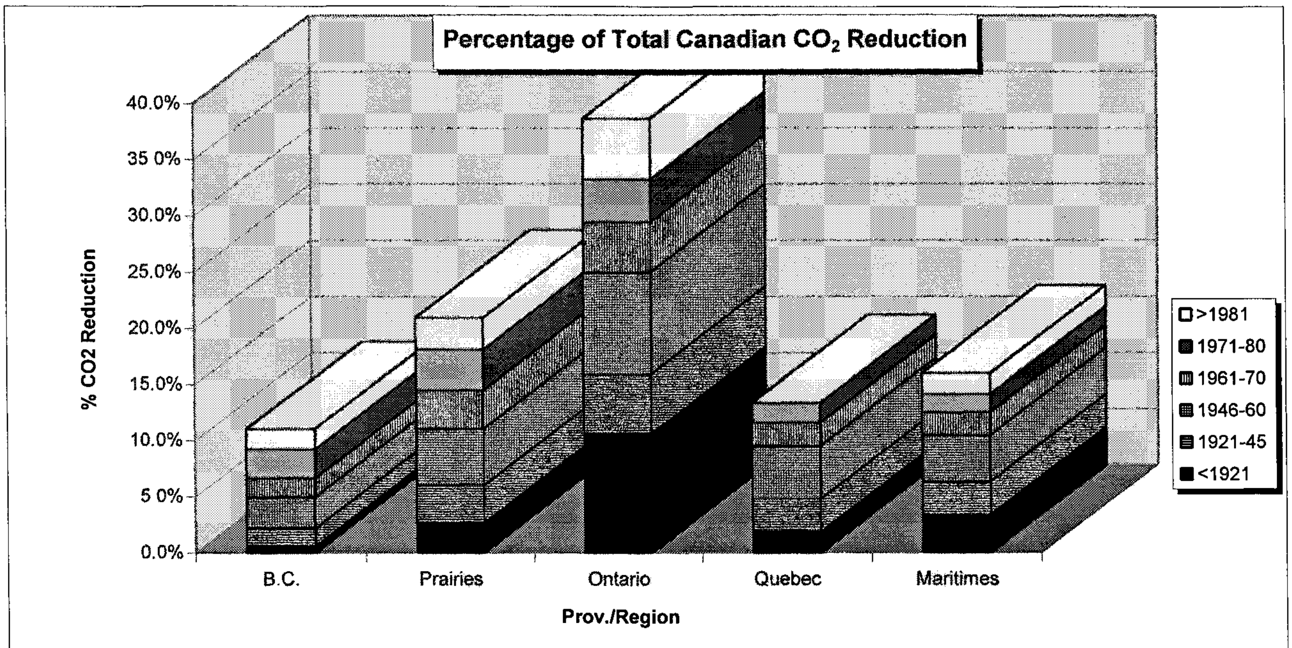
Max. Exterior (urban): 3 00 RSI

Mechanical systems:

Space heating:	upgrade	Ventilation control: iaq_opt
Domestic hot water:	upgrade	no ventilation in summer

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Age	Housing Stock	% of Total Canadian CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction (kilotonnes/yr)	(%)	Energy Savings (PJ/year)	(%)
<1921	666,980	0.6%	2.6%	10.6%	1.9%	3.4%	**19.0%**	5,785	60%	98.0	56%
1921-45	684,173	1.6%	3.4%	5.4%	2.9%	3.0%	**16.2%**	4,939	62%	79.2	56%
1946-60	1,356,041	2.8%	5.0%	9.1%	4.7%	4.1%	**25.8%**	7,859	57%	136.7	51%
1961-70	875,044	1.7%	3.5%	4.4%	2.1%	2.0%	**13.7%**	4,161	52%	80.5	48%
1971-80	1,156,834	2.6%	3.6%	3.8%	1.8%	1.7%	**13.4%**	4,095	46%	93.1	45%
>1981	919,050	1 8%	2 8%	5 4%	0 0%	1 8%	**11.9%**	3,622	44%	75 0	41%
Total	5,658,122	11.0%	20.9%	38.7%	13.4%	16.0%	**100.0%**	30,460	**54%**	562.5	**49%**



Age	Housing Stock	Retrofit (%)	ENERGY RELATED RETROFIT COSTS B.C. (10^6 $)	Prairies (10^6 $)	Ontario (10^6 $)	Quebec (10^6 $)	Maritimes (10^6 $)	Canada (10^6 $)	Canada Total Cost (10^6 $)
<1921	666,980	100%	434	1,406	4,144	1,816	1,189	8,989	17,361
1921-45	684,173	100%	1,456	2,150	2,815	1,484	1,012	8,916	17,123
1946-60	1,356,041	100%	2,656	3,654	6,768	3,421	1,654	18,153	36,712
1961-70	875,044	100%	1,818	2,323	3,996	2,531	1,075	11,741	24,207
1971-80	1,156,834	100%	3,005	3,573	3,996	3,007	1,679	15,259	31,356
>1981	919,050	100%	1,491	1,023	3,892	1,584	727	8,717	21,266
Total	5,658,122	100%	**10,859**	**14,128**	**25,610**	**13,842**	**7,337**	**71,775**	**148,025**

Normalized Total Energy Use (Existing Single-Detached Houses) for HIGH Scenario

Base

Run ID: H99C01

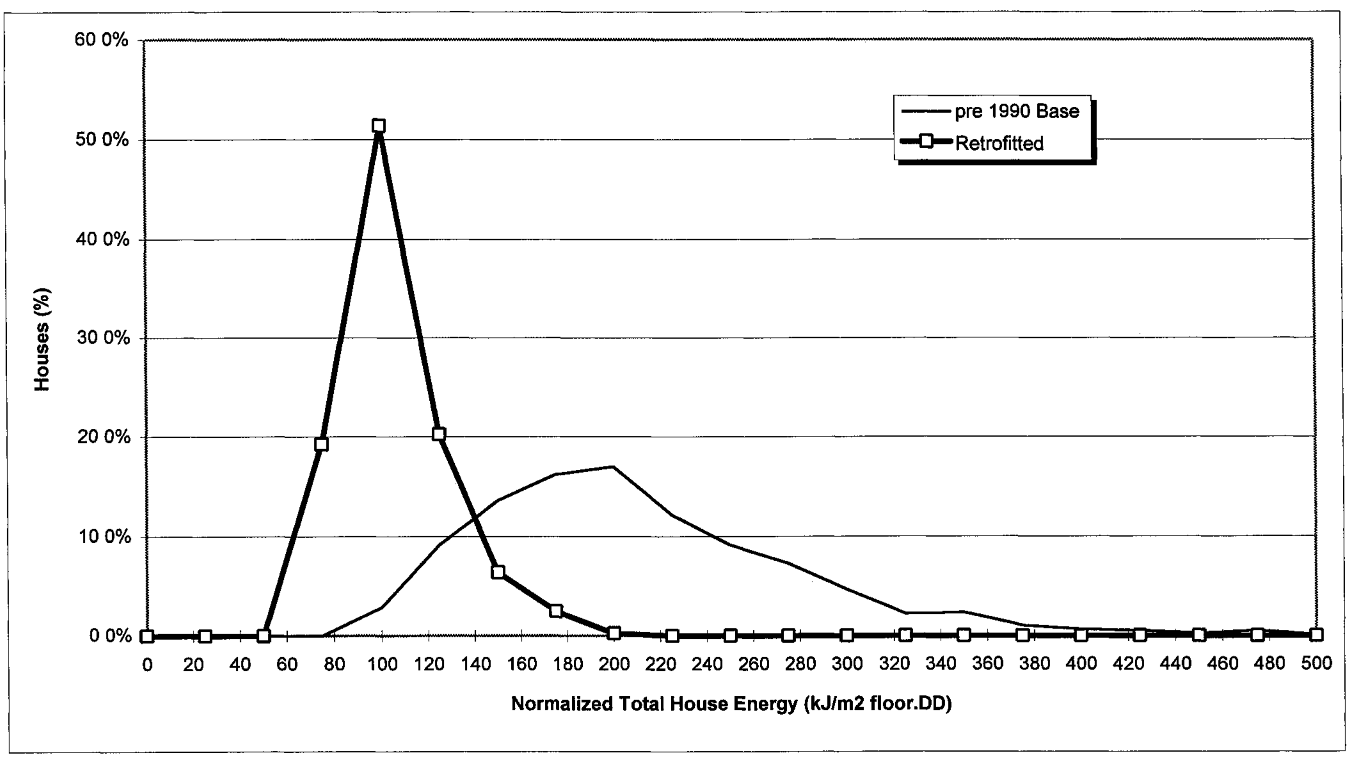
				Base	Retrofitted		
Impact:	**minimize Cost**						
Cutoff for retrofit:	**$999**	/GJ equiv	Average	**198**	**93**	kJ/m²DD	**Note:**
Houses retrofitted:	0%	of total	Minimum	76	52	kJ/m²DD	Results are for 765 houses
Energy reduction:	49%	of total **source** use	Maximum	553	189	kJ/m²DD	(unweighted by region or age)

Base Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	Cumulative houses less than threshold %	Normalized Energy use kJ/m²DD	Houses no.	Houses %
0	0	0.0%	0	0	0.0%
25	0	0.0%	0 to 25	0	0.0%
50	0	0.0%	25 to 50	0	0.0%
75	0	0.0%	50 to 75	0	0.0%
100	22	2.9%	75 to 100	22	2.9%
125	92	12.0%	100 to 125	70	9.2%
150	196	25.6%	125 to 150	104	13.6%
175	320	41.8%	150 to 175	124	16.2%
200	450	58.8%	175 to 200	130	17.0%
225	543	71.0%	200 to 225	93	12.2%
250	613	80.1%	225 to 250	70	9.2%
275	669	87.5%	250 to 275	56	7.3%
300	705	92.2%	275 to 300	36	4.7%
325	722	94.4%	300 to 325	17	2.2%
350	740	96.7%	325 to350	18	2.4%
375	748	97.8%	350 to 375	8	1.0%
400	753	98.4%	375 to 400	5	0.7%
425	757	99.0%	400 to 425	4	0.5%
450	759	99.2%	425 to 450	2	0.3%
475	763	99.7%	450 to 475	4	0.5%
500	764	99.9%	475 to 500	1	0.1%
525	764	99.9%	500 to 525	0	0.0%
550	764	99.9%	525 to 550	0	0.0%
575	765	100.0%	550 to 575	1	0.1%
600	765	100.0%	575 to 600	0	0.0%
			Total	765	

Retrofitted Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	Cumulative houses less than threshold %	Normalized Energy use kJ/m²DD	Houses no.	Houses %
0	0	0.0%	0	0	0.0%
25	0	0.0%	0 to 25	0	0.0%
50	0	0.0%	25 to 50	0	0.0%
75	147	19.2%	50 to 75	147	19.2%
100	540	70.6%	75 to 100	393	51.4%
125	695	90.8%	100 to 125	155	20.3%
150	744	97.3%	125 to 150	49	6.4%
175	763	99.7%	150 to 175	19	2.5%
200	765	100.0%	175 to 200	2	0.3%
225	765	100.0%	200 to 225	0	0.0%
250	765	100.0%	225 to 250	0	0.0%
275	765	100.0%	250 to 275	0	0.0%
300	765	100.0%	275 to 300	0	0.0%
325	765	100.0%	300 to 325	0	0.0%
350	765	100.0%	325 to350	0	0.0%
375	765	100.0%	350 to 375	0	0.0%
400	765	100.0%	375 to 400	0	0.0%
425	765	100.0%	400 to 425	0	0.0%
450	765	100.0%	425 to 450	0	0.0%
475	765	100.0%	450 to 475	0	0.0%
500	765	100.0%	475 to 500	0	0.0%
525	765	100.0%	500 to 525	0	0.0%
550	765	100.0%	525 to 550	0	0.0%
575	765	100.0%	550 to 575	0	0.0%
600	765	100.0%	575 to 600	0	0.0%
			Total	765	



Canadian Single Detached Residential Retrofit Program

Run ID: **H12C01**

Description: **Description:**

Assumptions:

Retrofit Goal: **HIGH** (Increase 30% over MID)

Impact: **minimize Cost**

	Main floor	Basement
Interior finish:	**strip**	**strip**
Exterior finish:	**strip**	**retain**
Water consumption:	**20%**	reduction
Utilities consumption:	**20%**	reduction*

*(except with combustion heating & hydroelectric utilities)

Mechanical systems:

Space heating: **upgrade**
Domestic hot water: **upgrade**
Ventilation control: **iaq_opt**
no ventilation in summer

Amortization period: **30** years
Present Worth Factor: **18.0**
Retrofit if less than: **$12.00** /GJ equiv.
(energy retrofit cost/life-cycle net energy)

Max. Exterior wall (urban)
3.00 RSI added

Canadian Single Detached Housing Projections: Demolition rate = 8.% of new housing

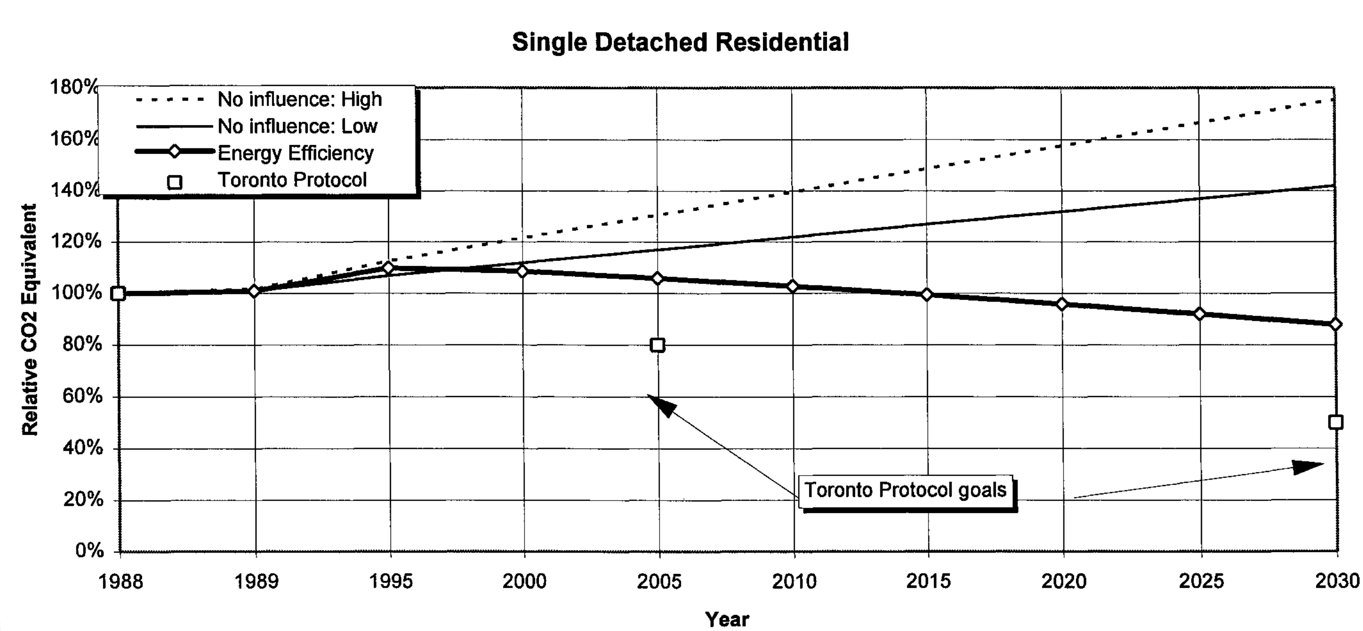
New housing are all houses built after 1989; Old housing are not retrofitted pre-1989; Retrofits are accumulated totals to date.

Year	1989	1995	2000	2005	2010	2015	2020	2025	2030
Old housing	5,658,122	5,612,310	4,947,943	4,285,497	3,624,295	2,963,795	2,303,423	1,643,050	982,622
Retrofits	0	0	631,905	1,264,027	1,896,286	2,528,612	3,160,930	3,793,219	4,425,474
New Housing	0	545,032	927,472	1,281,787	1,616,794	1,939,932	2,258,948	2,576,003	2,892,128
Total Housing	5,658,122	6,157,342	6,507,320	6,831,311	7,137,375	7,432,339	7,723,301	8,012,272	8,300,223
New Housing energy use and pollutant generation based on 1989 housing values, multiplied by:									
Relative to 1989:	100%	90%	81%	73%	66%	59%	53%	48%	43%

Results:

80.8% of original (1989) housing stock had potential for retrofit, however only 77.2%of original stock were actually retrofitted

With full implementation of potential retrofits, 1989 housing stock would generate 49.5% as much CO2 (operations only)



Year	Energy Efficiency Option: Energy Retrofit Costs ($ 10^6/yr)	Total energy (source) (%)	Pollutant Generation due to Operation & Retrofits: CO2 (%)	CO (%)	NOx (%)	CH4 (%)	CO2 Equivalent (%)	Toronto Protocol Goals (%)	No Influence Options: Low est. CO2 Equivalent (%)	High est. CO2 Equivalent (%)
1988	0	100%	100%	100%	100%	100%	100%	**100%**	100%	100%
1989	0	101%	101%	101%	101%	101%	101%		101%	102%
1995	0	116%	109%	117%	104%	115%	110%		107%	113%
2000	1,412	114%	108%	122%	97%	116%	109%		112%	122%
2005	1,412	**112%**	105%	124%	90%	115%	**106%**	**80%**	**117%**	**131%**
2010	1,412	110%	101%	125%	83%	114%	103%		122%	140%
2015	1,413	107%	98%	127%	75%	112%	100%		127%	149%
2020	1,413	104%	94%	127%	68%	110%	96%		132%	158%
2025	1,413	100%	89%	128%	60%	107%	92%		137%	167%
2030	1,412	**97%**	**85%**	**128%**	**53%**	**104%**	**88%**	**50%**	**142%**	**176%**
2030		58%	53%	88%	41%	55%	**60%**	< Existing housing stock only		

Note: Energy Efficiency Option values calculated on basis of 1989 values, then adjusted by estimated increases from 1988 to 1989

Retrofit of Canadian Houses: HIGH Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: H12C01

Base

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:

Space heating: upgrade

Domestic hot water: upgrade

Ventilation control: iaq_opt

Operations:

DHW: 20% reduction

Utilities: 20% reduction

Region	Age	Number of Houses Retrofitted	Volume (m^3)	Floor area (incl bsmt) (m^2)	Natural air change Base ac/h	Natural air change Upgrade ac/h	Total air change Base ac/h	Total air change Upgrade ac/h	Ventilation more than 0.4 ac/h	Interior retrofits: Ventilation less than 0.25 ac/h**	Interior retrofits: % of stock	Walls Base RSI	Walls Upgrade RSI
B C	<1921	9	478	186	0 70	0 32	0 70	0 34	10%	0%	0%	1 27	3 24
	1921-45	12	458	182	0 60	0 31	0 60	0 33	5%	0%	0%	1 45	3 29
	1946-60	24	441	165	0 53	0 33	0 53	0 35	9%	0%	0%	1 81	3 26
	1961-70	19	514	190	0 44	0 28	0 44	0 31	3%	0%	0%	1 97	3 24
	1971-80	6	553	181	0 39	0 31	0 39	0 33	6%	0%	0%	2 20	3 27
	>1981	18	687	268	0 21	0 17	0 53	0 25	0%	0%	0%	2 35	3 24
Prairies	<1921	11	407	150	0 54	0 21	0 54	0 29	0%	0%	9%	2 06	3 64
	1921-45	16	369	136	0 47	0 19	0 47	0 28	0%	0%	13%	2 10	4 13
	1946-60	41	417	155	0 31	0 19	0 31	0 28	2%	0%	7%	1 98	3 72
	1961-70	45	495	181	0 27	0 16	0 27	0 26	0%	0%	8%	2 12	3 72
	1971-80	37	485	183	0 20	0 14	0 20	0 27	0%	0%	5%	2 33	4 03
	>1981	40	593	226	0 22	0 13	0 44	0 26	0%	0%	0%	3 62	3 64
Ontario	<1921	14	520	186	0 78	0 37	0 78	0 40	50%	0%	100%	1 43	3 23
	1921-45	19	416	150	0 61	0 30	0 61	0 34	5%	0%	100%	1 49	3 19
	1946-60	49	507	192	0 37	0 22	0 37	0 28	2%	0%	0%	1 71	3 30
	1961-70	23	529	200	0 33	0 21	0 33	0 27	0%	0%	0%	2 05	3 68
	1971-80	21	475	182	0 28	0 19	0 28	0 27	0%	0%	4%	2 21	3 70
	>1981	41	847	321	0 19	0 16	0 24	0 26	0%	0%	0%	2 55	3 31
Quebec	<1921	6	506	187	0 60	0 22	0 60	0 28	0%	0%	14%	2 72	6 01
	1921-45	11	442	163	0 54	0 20	0 54	0 29	9%	0%	18%	2 01	6 51
	1946-60	44	476	173	0 40	0 19	0 40	0 28	4%	0%	33%	1 96	6 12
	1961-70	18	451	178	0 32	0 18	0 32	0 27	0%	0%	23%	2 28	5 99
	1971-80	15	441	160	0 28	0 17	0 28	0 27	0%	0%	14%	2 43	6 30
	>1981	2	471	192	0 15	0 21	0 15	0 27	0%	0%	0%	3 64	5 09
Maritimes	<1921	3	367	138	0 79	0 35	0 79	0 36	33%	0%	0%	2 50	3 60
	1921-45	5	338	127	0 89	0 34	0 89	0 36	40%	0%	0%	2 08	4 84
	1946-60	11	433	157	0 60	0 26	0 60	0 31	18%	0%	27%	1 90	5 66
	1961-70	14	470	166	0 49	0 23	0 49	0 30	0%	0%	57%	1 79	6 12
	1971-80	24	463	174	0 37	0 20	0 37	0 27	0%	0%	9%	2 25	5 43
	>1981	10	625	239	0 17	0 15	0 44	0 25	0%	0%	0%	3 70	4 78
CANADA	<1921	43	455	169	0 68	0 30	0 68	0 34	28%	0%	48%	2 00	3 94
	1921-45	63	405	152	0 62	0 27	0 62	0 32	8%	0%	41%	1 83	4 39
	1946-60	169	455	168	0 44	0 24	0 44	0 30	5%	0%	10%	1 87	4 41
	1961-70	119	492	183	0 37	0 21	0 37	0 28	1%	0%	12%	2 04	4 55
	1971-80	103	483	176	0 30	0 20	0 30	0 28	1%	0%	6%	2 28	4 55
	>1981	111	644	249	0 19	0 16	0 36	0 26	0%	0%	0%	3 17	4 01
	Total:	**608**											
	Average:*		489	183	0 43	0 23	0 46	0 30	6%	0%	16%	2 20	4 31

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Retrofit of Canadian Houses: HIGH Scenario

Cutoff for retrofit:
$12.00 /GJ equiv

Base

		Ceiling		Above grade Bsmt		Windows (south)		Window	Energy Related Costs		Life cycle
		Base	Upgrade	Base	Upgrade	Base	Upgrade	/floor area	Retrofit Unit Cost	Total Cost	Unit Energy Cost
Region	Age	RSI	RSI	RSI	RSI	RSI	RSI	%	$	(10^6 $)	($/GJ/30y)
B C	<1921	1 88	9 42	0 91	3 31	0 26	0 42	9%	14,532	394	7 32
	1921-45	3 05	8 00	0 84	3 21	0 26	0 38	11%	14,331	837	8 63
	1946-60	3 72	8 85	1 13	3 07	0 28	0 39	14%	14,210	1,819	9 15
	1961-70	3 41	9 18	1 37	3 02	0 28	0 43	13%	13,652	1,194	9 35
	1971-80	3 53	8 23	1 35	3 00	0 29	0 40	13%	13,683	1,086	7 61
	>1981	4 60	7 64	1 17	2 78	0 36	0 36	12%	10,767	1,199	6 67
									Subtotal:	**6,530**	
Prairies	<1921	3 38	9 41	0 64	3 39	0 37	0 66	8%	12,673	1,406	5 64
	1921-45	3 62	9 51	0 56	3 44	0 36	0 59	8%	12,756	2,150	6 78
	1946-60	3 98	9 14	0 95	3 18	0 37	0 59	9%	12,513	3,429	7 30
	1961-70	3 24	8 51	0 95	3 00	0 35	0 54	9%	12,415	2,130	7 12
	1971-80	3 58	8 78	1 35	2 82	0 36	0 56	9%	13,116	3,113	8 66
	>1981	6 96	8 32	1 88	2 85	0 49	0 62	7%	6,560	1,000	4 03
									Subtotal:	**13,228**	
Ontario	<1921	3 37	9 47	0 65	3 52	0 35	0 48	9%	14,117	4,144	4 85
	1921-45	4 24	8 97	0 72	3 30	0 36	0 48	10%	11,527	2,815	6 38
	1946-60	4 11	8 60	0 75	3 19	0 37	0 47	10%	13,049	6,086	8 47
	1961-70	3 62	8 40	0 91	3 11	0 37	0 47	11%	13,694	3,282	9 00
	1971-80	3 98	8 02	1 35	2 76	0 35	0 48	11%	12,931	3,203	9 88
	>1981	5 69	7 54	1 44	2 45	0 36	0 49	8%	10,634	3,782	7 07
									Subtotal:	**23,311**	
Quebec	<1921	2 94	11 70	0 99	3 20	0 38	0 46	7%	14,250	1,562	7 41
	1921-45	3 68	11 70	0 90	3 49	0 38	0 48	8%	16,005	1,484	6 93
	1946-60	4 23	11 70	1 07	3 23	0 37	0 47	10%	14,639	3,159	7 53
	1961-70	3 67	11 70	1 31	2 95	0 37	0 48	11%	14,479	1,556	8 45
	1971-80	3 77	11 54	1 39	2 96	0 37	0 48	11%	13,928	1,699	9 10
	>1981	5 84	11 70	1 92	3 14	0 39	0 48	14%	9,583	95	10 02
									Subtotal:	**9,555**	
Maritimes	<1921	2 54	9 36	1 19	2 95	0 33	0 47	11%	11,382	1,189	5 20
	1921-45	1 73	10 30	0 92	3 39	0 35	0 49	9%	14,112	1,012	5 51
	1946-60	3 07	11 06	0 82	3 42	0 35	0 48	9%	14,228	1,654	5 61
	1961-70	2 89	11 53	0 89	3 30	0 36	0 49	9%	13,798	1,075	6 77
	1971-80	3 27	11 02	1 33	3 12	0 35	0 49	10%	13,513	1,209	7 79
	>1981	6 14	11 70	2 50	3 13	0 37	0 52	8%	8,266	465	4 00
									Subtotal:	**6,604**	
CANADA	<1921	2 82	9 87	0 88	3 27	0 34	0 50	9%	13,391	8,695	6 08
	1921-45	3 26	9 69	0 79	3 36	0 34	0 48	9%	13,746	8,297	6 84
	1946-60	3 82	9 87	0 95	3 22	0 35	0 48	10%	13,728	16,148	7 61
	1961-70	3 36	9 86	1 08	3 07	0 35	0 48	11%	13,608	9,237	8 14
	1971-80	3 62	9 52	1 35	2 93	0 34	0 48	11%	13,434	10,311	8 61
	>1981	5 85	9 38	1 78	2 87	0 39	0 49	10%	9,162	6,541	6 36
	Total:								**Total:**	**59,229**	
	Average:	3 79	9 70	1 14	3 12	0 35	0 49	10%	**$12,845** (unweighted)		7 27

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Retrofit of Canadian Houses: HIGH Scenario

Simulations using REES version 1 20

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: H12C01

Base

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

Retrofit rules: HIGH scenario (Increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Min. upgrade:	RSI	
Walls	0 50	added
Windows	0 10	added

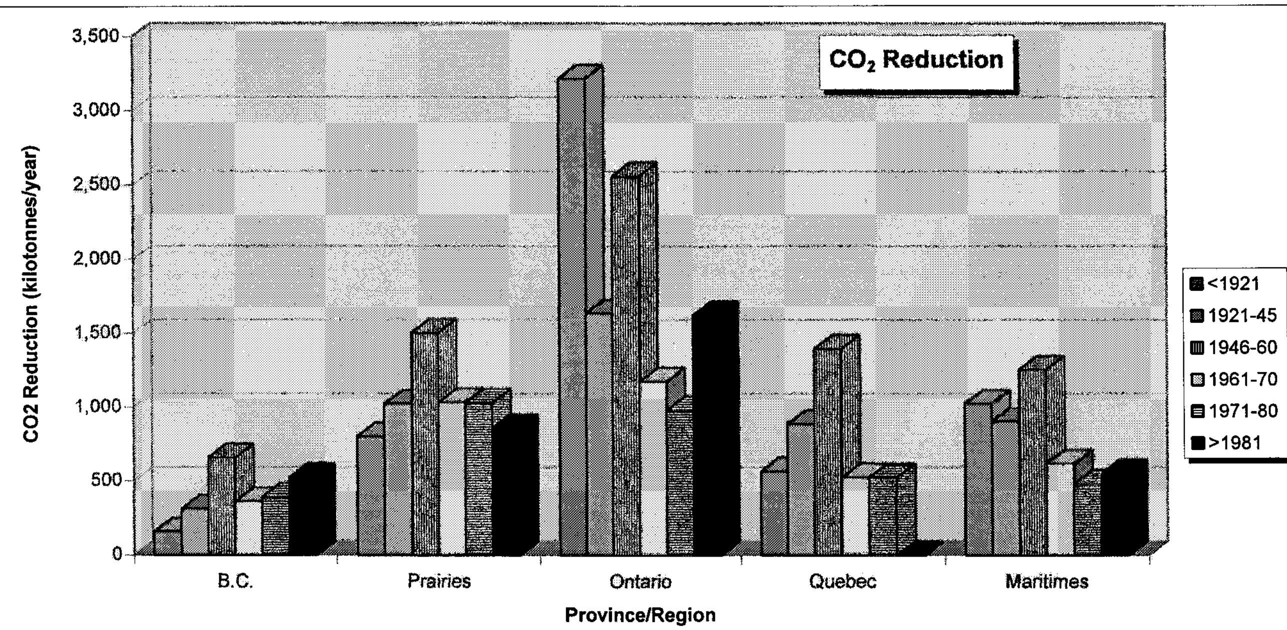
Max. Exterior (urban): 3 00 RSI added

Mechanical systems:

Space heating:	upgrade	Ventilation control: iaq_opt
Domestic hot water:	upgrade	no ventilation in summer

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Age	Housing Stock	B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction	CH4 Reduction	CO Reduction	NOx Reduction
		CO_2 reduction - Operation only (kilotonnes/yr)					(kilotonnes/yr)		(kilotonnes/yr)	(kilotonnes/yr)	(kilotonnes/yr)
<1921	666,980	159	801	3,218	567	1,026	**5,772**	60%	0.04	0.54	45.1
1921-45	684,173	311	1,023	1,637	888	902	**4,761**	60%	0.04	0.10	38.2
1946-60	1,356,041	657	1,504	2,561	1,397	1,257	**7,377**	53%	0.07	0.28	51.7
1961-70	875,044	363	1,034	1,178	526	620	**3,720**	46%	0.04	0.26	21.5
1971-80	1,156,834	392	1,031	983	525	482	**3,412**	39%	0.05	0.34	12.3
>1981	919,050	524	859	1,624	1	550	**3,558**	43%	0.07	0 40	4 8
Total	5,658,122	2,406	6,252	11,201	3,904	4,837	**28,600**	**51%**	0.31	1.92	173.6



Age	Housing Stock	CO_2 (kilotonnes)	payback (years)	CH4 (kilotonnes)	payback (years)	CO (kilotonnes)	payback (years)	NOx (kilotonnes)	payback (years)	Used (PJ)	Payback (years)
		RETROFIT EMBODIED: POLLUTANTS								RETROFIT ENERGY	
<1921	666,980	1,689	0.3	0.04	0.9	2.3	4.3	4.7	0.1	43.7	0.5
1921-45	684,173	1,550	0.3	0.03	0.9	2.3	23.1	4.3	0.1	39.2	0.5
1946-60	1,356,041	3,132	0.4	0.06	0.9	3.8	13.7	8.3	0.2	81.4	0.6
1961-70	875,044	1,832	0.5	0.04	0.9	2.1	8.1	4.9	0.2	48.1	0.7
1971-80	1,156,834	2,120	0.6	0.04	0.9	2.3	6.8	5.6	0.5	55.4	0.8
>1981	919,050	1,605	0 5	0 03	0 5	2 1	5 2	4 1	0 8	43 8	0 6
Total	5,658,122	11,927	0.4	0.25	0.8	14.9	7.8	31.9	0.2	312	0.6

Retrofit of Canadian Houses: HIGH Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls — 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) — 1989

Retrofit rules: HIGH scenario (Increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

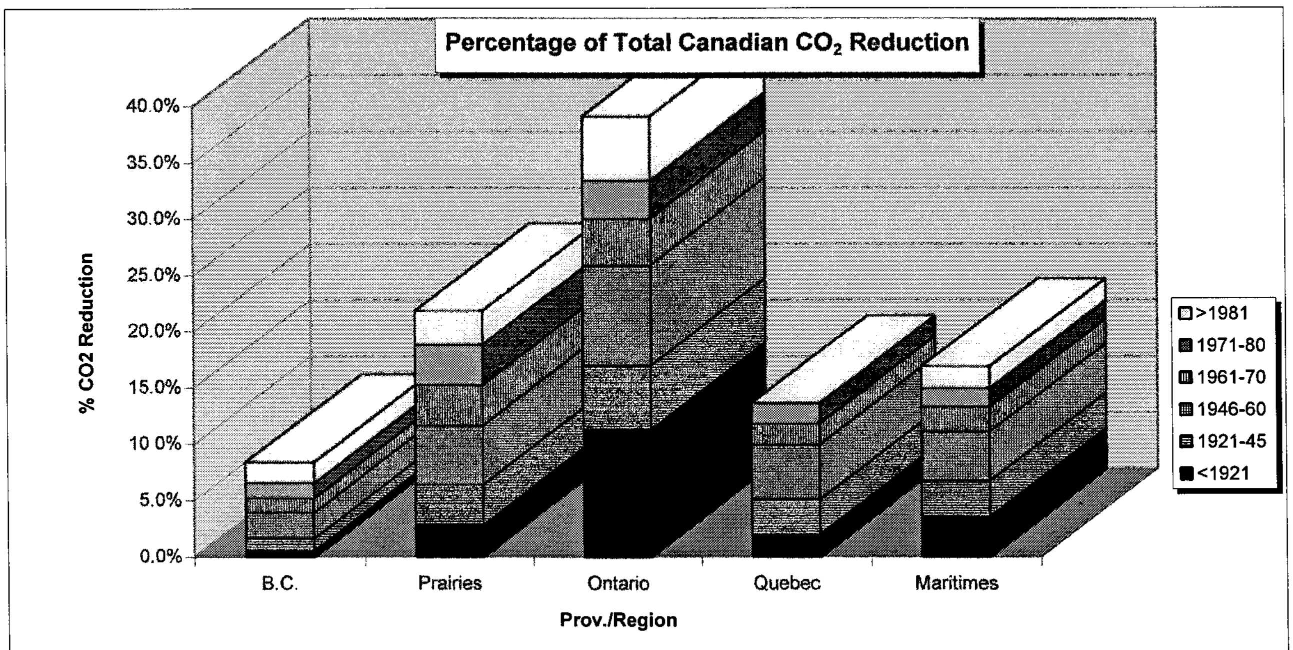
Cutoff for retrofit: **$12.00** /GJ equiv
Run ID: H12C01
Base

Min. upgrade:	RSI
Walls	0 50
Windows	0 10

Max. Exterior (urban): 3 00 RSI

Mechanical systems:
Space heating: upgrade — Ventilation control: iaq_opt
Domestic hot water: upgrade — no ventilation in summer

Age	Housing Stock	% of Total Canadian CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction (kilotonnes/yr)	(%)	Energy Savings (PJ/year)	(%)
<1921	666,980	0.6%	2.8%	11.3%	2.0%	3.6%	**20.2%**	5,772	60%	96.7	56%
1921-45	684,173	1.1%	3.6%	5.7%	3.1%	3.2%	**16.6%**	4,761	60%	76.7	54%
1946-60	1,356,041	2.3%	5.3%	9.0%	4.9%	4.4%	**25.8%**	7,377	53%	128.6	48%
1961-70	875,044	1.3%	3.6%	4.1%	1.8%	2.2%	**13.0%**	3,720	46%	69.7	41%
1971-80	1,156,834	1.4%	3.6%	3.4%	1.8%	1.7%	**11.9%**	3,412	39%	72.7	35%
>1981	919,050	1 8%	3 0%	5 7%	0 0%	1 9%	**12.4%**	3,558	43%	68 6	37%
Total	5,658,122	8.4%	21.9%	39.2%	13.6%	16.9%	**100.0%**	28,600	**51%**	513.0	**45%**



Age	Housing Stock	Retrofit (%)	ENERGY RELATED RETROFIT COSTS B.C. (10^6 \$)	Prairies (10^6 \$)	Ontario (10^6 \$)	Quebec (10^6 \$)	Maritimes (10^6 \$)	Canada (10^6 \$)	Canada Total Cost (10^6 \$)
<1921	666,980	96%	394	1,406	4,144	1,562	1,189	8,695	16,825
1921-45	684,173	86%	837	2,150	2,815	1,484	1,012	8,297	15,931
1946-60	1,356,041	88%	1,819	3,429	6,086	3,159	1,654	16,148	32,672
1961-70	875,044	79%	1,194	2,130	3,282	1,556	1,075	9,237	19,249
1971-80	1,156,834	70%	1,086	3,113	3,203	1,699	1,209	10,311	21,332
>1981	919,050	71%	1,199	1,000	3,782	95	465	6,541	16,301
Total	5,658,122	81%	**6,530**	**13,228**	**23,311**	**9,555**	**6,604**	**59,229**	**122,310**

Normalized Total Energy Use (Existing Single-Detached Houses) for HIGH Scenario

Base

Run ID: H12C01

Impact: **minimize Cost**

				Base	Retrofitted	
Cutoff for retrofit:	**$12.00**	/GJ equiv	Average	**211**	**94**	kJ/m²DD
Houses retrofitted:	81%	of total	Minimum	93	53	kJ/m²DD
Energy reduction:	45%	of total **source** use	Maximum	553	189	kJ/m²DD

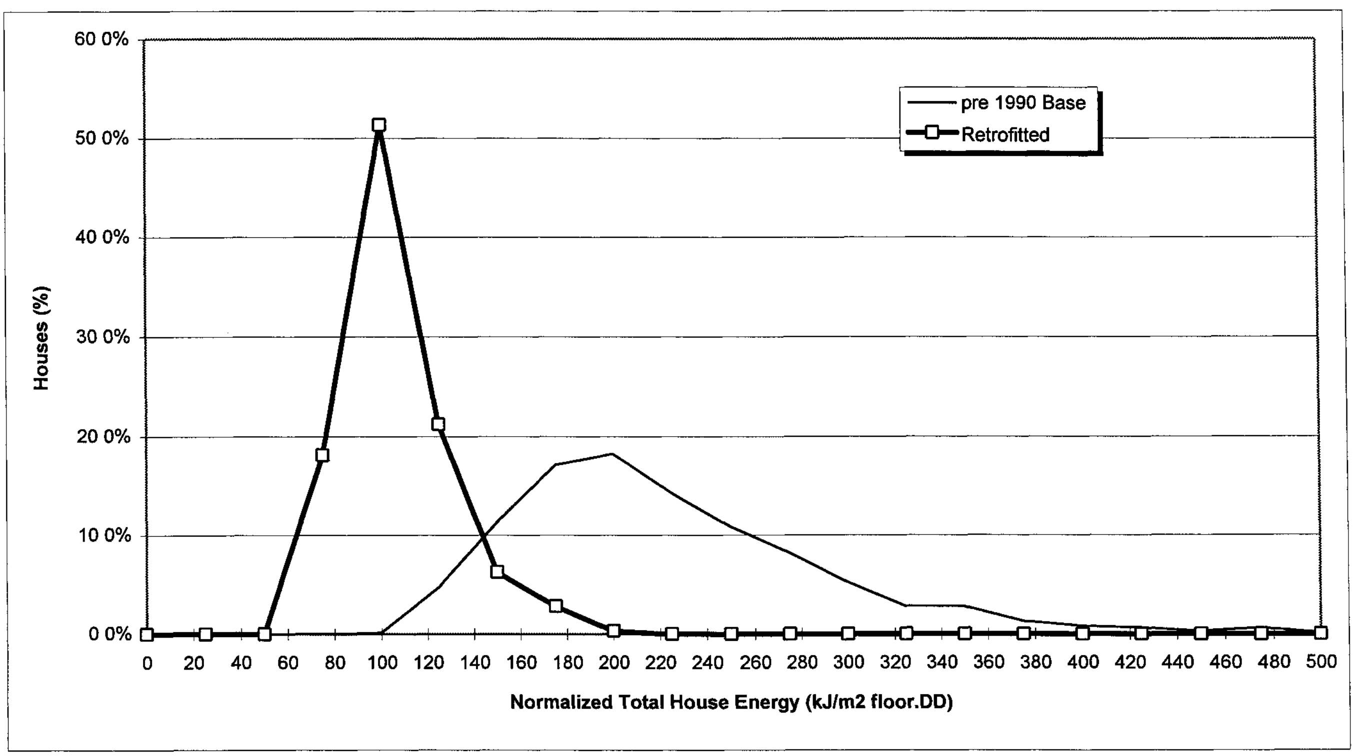
Note:
Results are for 608 houses
(unweighted by region or age)

Base Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	0	0 0%	50 to 75	0	0 0%
100	1	0 2%	75 to 100	1	0 2%
125	30	4 9%	100 to 125	29	4 8%
150	99	16 3%	125 to 150	69	11 3%
175	203	33 4%	150 to 175	104	17 1%
200	314	51 6%	175 to 200	111	18 3%
225	401	66 0%	200 to 225	87	14 3%
250	467	76 8%	225 to 250	66	10 9%
275	517	85 0%	250 to 275	50	8 2%
300	549	90 3%	275 to 300	32	5 3%
325	566	93 1%	300 to 325	17	2 8%
350	583	95 9%	325 to350	17	2 8%
375	591	97 2%	350 to 375	8	1 3%
400	596	98 0%	375 to 400	5	0 8%
425	600	98 7%	400 to 425	4	0 7%
450	602	99 0%	425 to 450	2	0 3%
475	606	99 7%	450 to 475	4	0 7%
500	607	99 8%	475 to 500	1	0 2%
525	607	99 8%	500 to 525	0	0 0%
550	607	99 8%	525 to 550	0	0 0%
575	608	100 0%	550 to 575	1	0 2%
600	608	100 0%	575 to 600	0	0 0%
			Total	608	

Retrofitted Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	110	18 1%	50 to 75	110	18 1%
100	422	69 4%	75 to 100	312	51 3%
125	551	90 6%	100 to 125	129	21 2%
150	589	96 9%	125 to 150	38	6 3%
175	606	99 7%	150 to 175	17	2 8%
200	608	100 0%	175 to 200	2	0 3%
225	608	100 0%	200 to 225	0	0 0%
250	608	100 0%	225 to 250	0	0 0%
275	608	100 0%	250 to 275	0	0 0%
300	608	100 0%	275 to 300	0	0 0%
325	608	100 0%	300 to 325	0	0 0%
350	608	100 0%	325 to350	0	0 0%
375	608	100 0%	350 to 375	0	0 0%
400	608	100 0%	375 to 400	0	0 0%
425	608	100 0%	400 to 425	0	0 0%
450	608	100 0%	425 to 450	0	0 0%
475	608	100 0%	450 to 475	0	0 0%
500	608	100 0%	475 to 500	0	0 0%
525	608	100 0%	500 to 525	0	0 0%
550	608	100 0%	525 to 550	0	0 0%
575	608	100 0%	550 to 575	0	0 0%
600	608	100 0%	575 to 600	0	0 0%
			Total	608	



Retrofit of Canadian Houses: HIGH Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: H12C02
Continuous fan

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:
Space heating: upgrade
Domestic hot water: upgrade
Ventilation control: continuous

Operations:
DHW: 20% reduction
Utilities: 20% reduction

Region	Age	Number of Houses Retrofitted	Volume (m^3)	Floor area (incl bsmt) (m^2)	Natural air change Base ac/h	Natural air change Upgrade ac/h	Total air change Base ac/h	Total air change Upgrade ac/h	Ventilation more than 0.4 ac/h	Interior retrofits: Ventilation less than 0.25 ac/h**	Interior retrofits: % of stock	Walls Base RSI	Walls Upgrade RSI
B C	<1921	9	478	186	0 70	0 32	0 70	0 48	90%	0%	0%	1 27	3 24
	1921-45	12	458	182	0 60	0 31	0 60	0 47	50%	0%	0%	1 45	3 29
	1946-60	19	441	164	0 53	0 34	0 53	0 51	49%	0%	0%	1 81	3 27
	1961-70	15	514	188	0 44	0 27	0 44	0 43	41%	0%	0%	1 97	3 25
	1971-80	6	553	181	0 39	0 31	0 39	0 47	31%	0%	0%	2 20	3 27
	>1981	18	687	268	0 21	0 17	0 53	0 35	5%	0%	0%	2 35	3 24
Prairies	<1921	11	407	150	0 54	0 21	0 54	0 40	36%	0%	9%	2 06	3 64
	1921-45	16	369	136	0 47	0 19	0 47	0 39	31%	0%	13%	2 10	4 13
	1946-60	39	417	156	0 31	0 19	0 31	0 38	16%	0%	7%	1 98	3 74
	1961-70	42	495	180	0 27	0 17	0 27	0 37	10%	0%	8%	2 12	3 74
	1971-80	30	485	187	0 20	0 15	0 20	0 36	7%	0%	2%	2 33	4 08
	>1981	40	593	226	0 22	0 13	0 44	0 35	3%	0%	0%	3 62	3 64
Ontario	<1921	14	520	186	0 78	0 37	0 78	0 56	100%	0%	100%	1 43	3 23
	1921-45	19	416	150	0 61	0 30	0 61	0 48	95%	0%	100%	1 49	3 19
	1946-60	43	507	195	0 37	0 22	0 37	0 40	25%	0%	0%	1 71	3 22
	1961-70	20	529	205	0 33	0 21	0 33	0 39	14%	0%	0%	2 05	3 76
	1971-80	11	475	168	0 28	0 21	0 28	0 38	4%	0%	4%	2 21	4 10
	>1981	37	847	308	0 19	0 17	0 24	0 36	7%	0%	0%	2 55	3 31
Quebec	<1921	6	506	187	0 60	0 22	0 60	0 40	29%	0%	14%	2 72	6 01
	1921-45	11	442	163	0 54	0 20	0 54	0 40	18%	0%	18%	2 01	6 51
	1946-60	41	476	172	0 40	0 19	0 40	0 39	27%	0%	33%	1 96	6 13
	1961-70	17	451	178	0 32	0 18	0 32	0 38	13%	0%	23%	2 28	5 95
	1971-80	11	441	162	0 28	0 17	0 28	0 38	4%	0%	11%	2 43	6 14
	>1981	1	471	214	0 15	0 21	0 15	0 37	0%	0%	0%	3 64	4 62
Maritimes	<1921	3	367	138	0 79	0 35	0 79	0 51	100%	0%	0%	2 50	3 60
	1921-45	5	338	127	0 89	0 34	0 89	0 50	80%	0%	0%	2 08	4 84
	1946-60	11	433	157	0 60	0 26	0 60	0 44	73%	0%	27%	1 90	5 66
	1961-70	13	470	163	0 49	0 23	0 49	0 42	57%	0%	57%	1 79	6 07
	1971-80	22	463	176	0 37	0 20	0 37	0 38	12%	0%	6%	2 25	5 33
	>1981	10	625	239	0 17	0 15	0 44	0 34	0%	0%	0%	3 70	4 78
CANADA	<1921	43	455	169	0 68	0 30	0 68	0 47	75%	0%	48%	2 00	3 94
	1921-45	63	405	152	0 62	0 27	0 62	0 45	60%	0%	41%	1 83	4 39
	1946-60	153	455	169	0 44	0 24	0 44	0 42	31%	0%	10%	1 87	4 41
	1961-70	107	492	183	0 37	0 21	0 37	0 40	21%	0%	12%	2 04	4 55
	1971-80	80	483	175	0 30	0 21	0 30	0 39	10%	0%	4%	2 28	4 58
	>1981	106	644	251	0 19	0 17	0 36	0 35	4%	0%	0%	3 17	3 92
	Total:	**552**											
	Average:*		489	183	0 43	0 23	0 46	0 41	30%	0%	16%	2 20	4 30

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Retrofit of Canadian Houses: HIGH Scenario

Cutoff for retrofit:
$12.00 /GJ equiv

Continuous fan

Region	Age	Ceiling Base RSI	Ceiling Upgrade RSI	Above grade Bsmt Base RSI	Above grade Bsmt Upgrade RSI	Windows (south) Base RSI	Windows (south) Upgrade RSI	Window /floor area %	Energy Related Costs: Retrofit Unit Cost $	Energy Related Costs: Total Cost (10^6 $)	Life cycle Unit Energy Cost ($/GJ/30y)
B C	<1921	1 88	9 42	0 91	3 31	0 26	0 42	9%	14,310	388	7 94
	1921-45	3 05	8 00	0 84	3 21	0 26	0 38	11%	14,110	824	9 28
	1946-60	3 72	8 68	1 13	3 07	0 28	0 38	14%	14,356	1,455	9 34
	1961-70	3 41	9 38	1 37	3 07	0 28	0 43	13%	13,236	914	9 78
	1971-80	3 53	8 23	1 35	3 00	0 29	0 40	13%	13,462	1,068	8 38
	>1981	4 60	7 64	1 17	2 78	0 36	0 36	12%	10,767	1,199	7 41
									Subtotal:	**5,849**	
Prairies	<1921	3 38	9 41	0 64	3 39	0 37	0 66	8%	12,454	1,382	6 03
	1921-45	3 62	9 51	0 56	3 44	0 36	0 59	8%	12,537	2,113	7 30
	1946-60	3 98	9 13	0 95	3 22	0 37	0 58	9%	12,353	3,220	7 77
	1961-70	3 24	8 45	0 95	3 02	0 35	0 52	8%	12,057	1,930	7 60
	1971-80	3 58	8 86	1 35	2 84	0 36	0 56	9%	13,289	2,558	9 10
	>1981	6 96	8 32	1 88	2 85	0 49	0 62	7%	6,489	989	4 74
									Subtotal:	**12,192**	
Ontario	<1921	3 37	9 47	0 65	3 52	0 35	0 48	9%	13,903	4,081	5 24
	1921-45	4 24	8 97	0 72	3 30	0 36	0 48	10%	11,313	2,762	6 96
	1946-60	4 11	8 60	0 75	3 22	0 37	0 47	10%	12,887	5,275	9 05
	1961-70	3 62	8 53	0 91	3 14	0 37	0 47	10%	13,506	2,815	9 75
	1971-80	3 98	8 30	1 35	2 86	0 35	0 49	12%	12,941	1,679	10 15
	>1981	5 69	7 54	1 44	2 45	0 36	0 49	8%	10,094	3,239	8 00
									Subtotal:	**19,851**	
Quebec	<1921	2 94	11 70	0 99	3 20	0 38	0 46	7%	14,036	1,538	8 32
	1921-45	3 68	11 70	0 90	3 49	0 38	0 48	8%	15,791	1,464	7 35
	1946-60	4 23	11 70	1 07	3 20	0 37	0 47	10%	14,526	2,921	7 85
	1961-70	3 67	11 70	1 31	2 99	0 37	0 48	11%	14,157	1,437	9 09
	1971-80	3 77	11 49	1 39	3 00	0 37	0 48	11%	14,091	1,261	9 01
	>1981	5 84	11 70	1 92	3 49	0 39	0 48	12%	11,146	55	10 86
									Subtotal:	**8,676**	
Maritimes	<1921	2 54	9 36	1 19	2 95	0 33	0 47	11%	11,168	1,167	5 69
	1921-45	1 73	10 30	0 92	3 39	0 35	0 49	9%	13,898	996	5 83
	1946-60	3 07	11 06	0 82	3 42	0 35	0 48	9%	14,014	1,630	5 96
	1961-70	2 89	11 52	0 89	3 37	0 36	0 48	10%	13,560	981	6 80
	1971-80	3 27	10 96	1 33	3 15	0 35	0 49	10%	13,231	1,085	8 30
	>1981	6 14	11 70	2 50	3 13	0 37	0 52	8%	8,245	464	4 96
									Subtotal:	**6,323**	
CANADA	<1921	2 82	9 87	0 88	3 27	0 34	0 50	9%	13,174	8,556	6 65
	1921-45	3 26	9 69	0 79	3 36	0 34	0 48	9%	13,530	8,159	7 35
	1946-60	3 82	9 84	0 95	3 23	0 35	0 48	10%	13,627	14,500	7 99
	1961-70	3 36	9 91	1 08	3 12	0 35	0 48	10%	13,303	8,077	8 61
	1971-80	3 62	9 57	1 35	2 97	0 34	0 48	11%	13,403	7,651	8 99
	>1981	5 85	9 38	1 78	2 94	0 39	0 49	9%	9,348	5,946	7 19
	Total:								**Total:**	**52,891**	
	Average:	3 79	9 71	1 14	3 15	0 35	0 49	10%	**$12,731**		7 80
									(unweighted)		

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Retrofit of Canadian Houses: HIGH Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Retrofit rules: HIGH scenario (increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

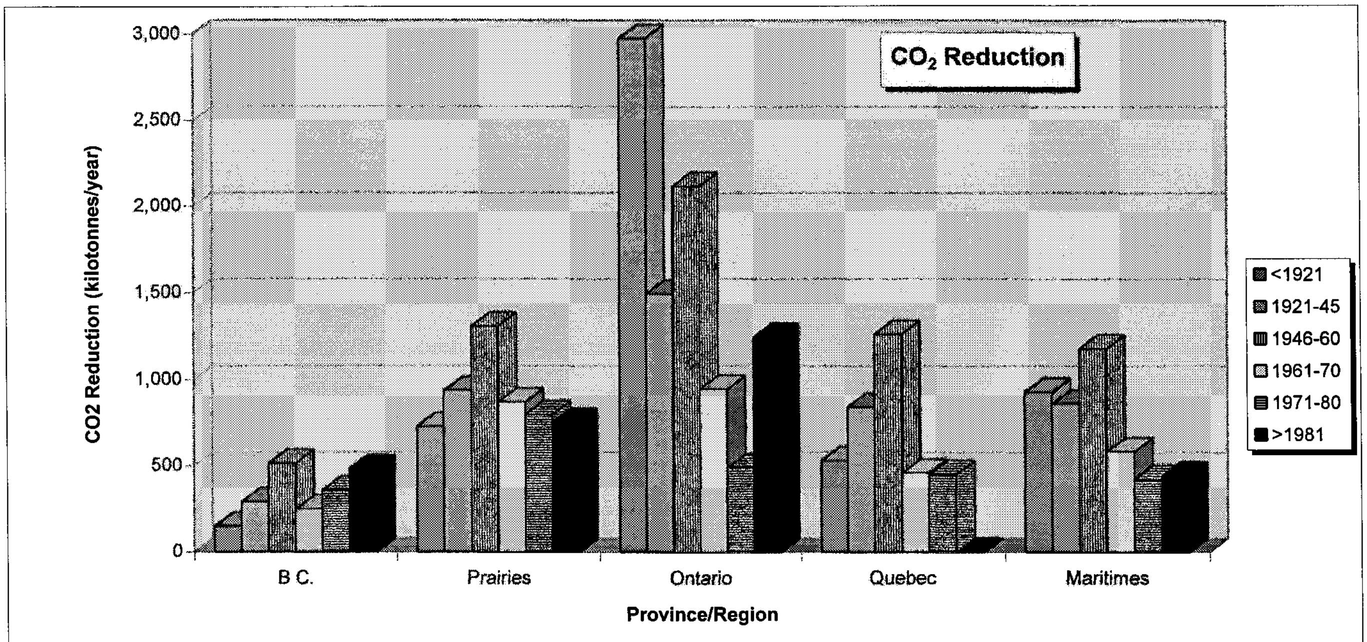
Cutoff for retrofit: **$12.00** /GJ equiv
Run ID: H12C02
Continuous fan

Min. upgrade:	RSI		Max. Exterior (urban)	
Walls	0 50	added	3 00	RSI added
Windows	0 10	added		

Mechanical systems:

Space heating:	upgrade	Ventilation control: continuous
Domestic hot water:	upgrade	no ventilation in summer

Age	Housing Stock	CO_2 reduction - Operation only B.C. (kilotonnes/yr)	Prairies	Ontario	Quebec	Maritimes	Canada (kilotonnes/yr)	CO_2 Reduction	CH4 Reduction (kilotonnes/yr)	CO Reduction (kilotonnes/yr)	NOx Reduction (kilotonnes/yr)
<1921	666,980	150	730	2,976	533	931	**5,319**	55%	0.04	0.42	42.1
1921-45	684,173	293	938	1,496	842	863	**4,433**	55%	0.03	0.03	36.0
1946-60	1,356,041	516	1,310	2,119	1,262	1,179	**6,385**	46%	0.06	0.11	46.1
1961-70	875,044	250	872	947	462	585	**3,116**	39%	0.03	0.17	19.1
1971-80	1,156,834	359	797	491	453	425	**2,525**	28%	0.04	0.26	9.7
>1981	919,050	485	752	1,246	1	445	**2,929**	35%	0.06	0 25	3 8
Total	5,658,122	2,053	5,399	9,273	3,553	4,428	**24,706**	**44%**	0.26	1.24	156.8



Age	Housing Stock	RETROFIT EMBODIED: POLLUTANTS CO_2 (kilotonnes)	payback (years)	CH4 (kilotonnes)	payback (years)	CO (kilotonnes)	payback (years)	NOx (kilotonnes)	payback (years)	RETROFIT ENERGY Used (PJ)	Payback (years)
<1921	666,980	1,689	0.3	0.04	0.9	2.3	5.4	4.7	0.1	43.7	0.5
1921-45	684,173	1,549	0.3	0.03	1.0	2.3	71.3	4.3	0.1	39.2	0.6
1946-60	1,356,041	2,845	0.4	0.06	1.0	3.4	30.7	7.6	0.2	73.7	0.7
1961-70	875,044	1,618	0.5	0.03	1.0	1.9	11.5	4.3	0.2	42.4	0.7
1971-80	1,156,834	1,588	0.6	0.03	0.9	1.7	6.6	4.2	0.4	41.3	0.8
>1981	919,050	1,454	0 5	0 03	0 5	1 9	7 6	3 7	1 0	39 5	0 7
Total	5,658,122	10,742	0.4	0.22	0.9	13.5	10.9	28.8	0.2	280	0.6

Retrofit of Canadian Houses: HIGH Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls — 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) — 1989

Retrofit rules: HIGH scenario (Increase 30% over MID), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 20% reduction
Utilities: 20% reduction*
*(except with combustion heating & hydroelectric utilities)

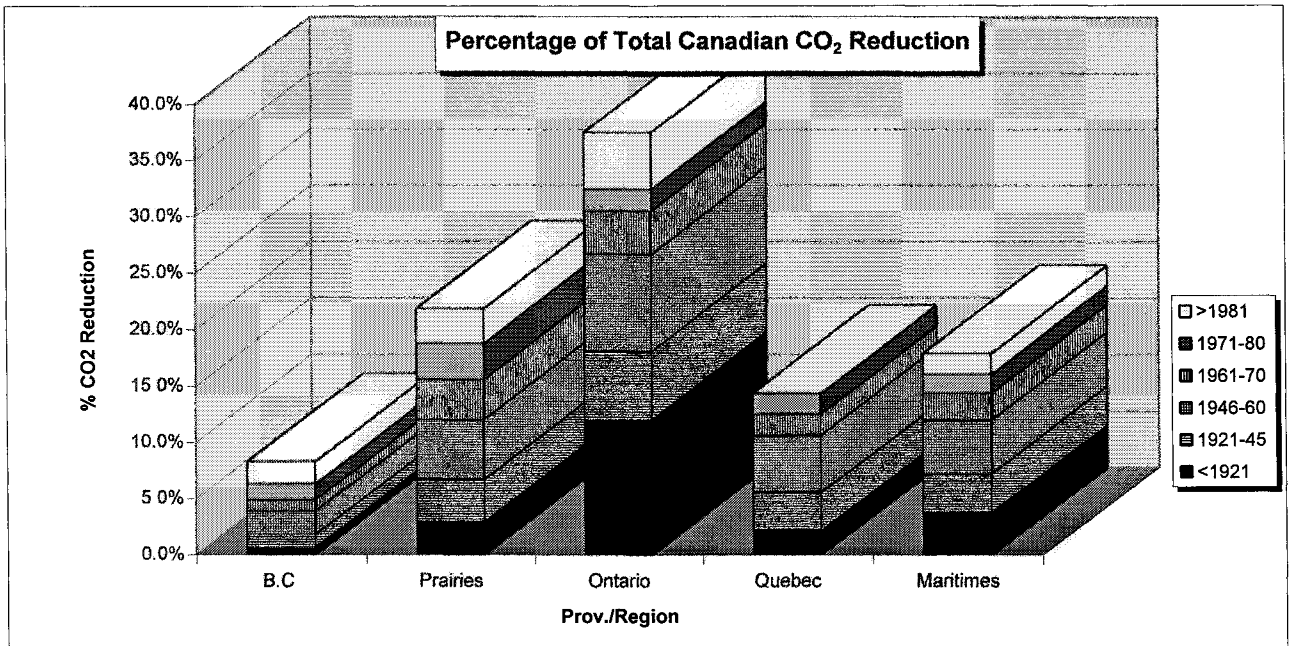
Min. upgrade:	RSI
Walls	0 50
Windows	0 10

Mechanical systems:
Space heating: upgrade — Ventilation control: continuous
Domestic hot water: upgrade — no ventilation in summer

Cutoff for retrofit: **$12.00** /GJ equiv
Run ID: H12C02
Continuous fan

Max. Exterior (urban): 3 00 RSI

Age	Housing Stock	% of Total Canadian CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction (kilotonnes/yr)	(%)	Energy Savings (PJ/year)	(%)
<1921	666,980	0.6%	3.0%	12.0%	2.2%	3.8%	**21.5%**	5,319	55%	88.3	51%
1921-45	684,173	1.2%	3.8%	6.1%	3.4%	3.5%	**17.9%**	4,433	55%	70.9	50%
1946-60	1,356,041	2.1%	5.3%	8.6%	5.1%	4.8%	**25.8%**	6,385	46%	110.1	41%
1961-70	875,044	1.0%	3.5%	3.8%	1.9%	2.4%	**12.6%**	3,116	39%	57.8	34%
1971-80	1,156,834	1.5%	3.2%	2.0%	1.8%	1.7%	**10.2%**	2,525	28%	53.0	25%
>1981	919,050	2 0%	3 0%	5 0%	0 0%	1 8%	**11.9%**	2,929	35%	56 2	31%
Total	5,658,122	8.3%	21.9%	37.5%	14.4%	17.9%	**100.0%**	24,706	**44%**	436.4	**38%**



Age	Housing Stock	Retrofit (%)	ENERGY RELATED RETROFIT COSTS B.C. (10^6 $)	Prairies (10^6 $)	Ontario (10^6 $)	Quebec (10^6 $)	Maritimes (10^6 $)	Canada (10^6 $)	Canada Total Cost (10^6 $)
<1921	666,980	96%	388	1,382	4,081	1,538	1,167	8,556	16,617
1921-45	684,173	86%	824	2,113	2,762	1,464	996	8,159	15,725
1946-60	1,356,041	79%	1,455	3,220	5,275	2,921	1,630	14,500	29,357
1961-70	875,044	71%	914	1,930	2,815	1,437	981	8,077	16,850
1971-80	1,156,834	54%	1,068	2,558	1,679	1,261	1,085	7,651	15,704
>1981	919,050	68%	1,199	989	3,239	55	464	5,946	14,746
Total	5,658,122	74%	**5,849**	**12,192**	**19,851**	**8,676**	**6,323**	**52,891**	**108,999**

Normalized Total Energy Use (Existing Single-Detached Houses) for HIGH Scenario

Continuous fan
Run ID: H12C02

Impact: **minimize Cost**

Cutoff for retrofit:	**$12.00**	/GJ equiv
Houses retrofitted:	74%	of total
Energy reduction:	38%	of total **source** use

	Base	Retrofitted	
Average	**215**	**104**	kJ/m²DD
Minimum	93	61	kJ/m²DD
Maximum	553	203	kJ/m²DD

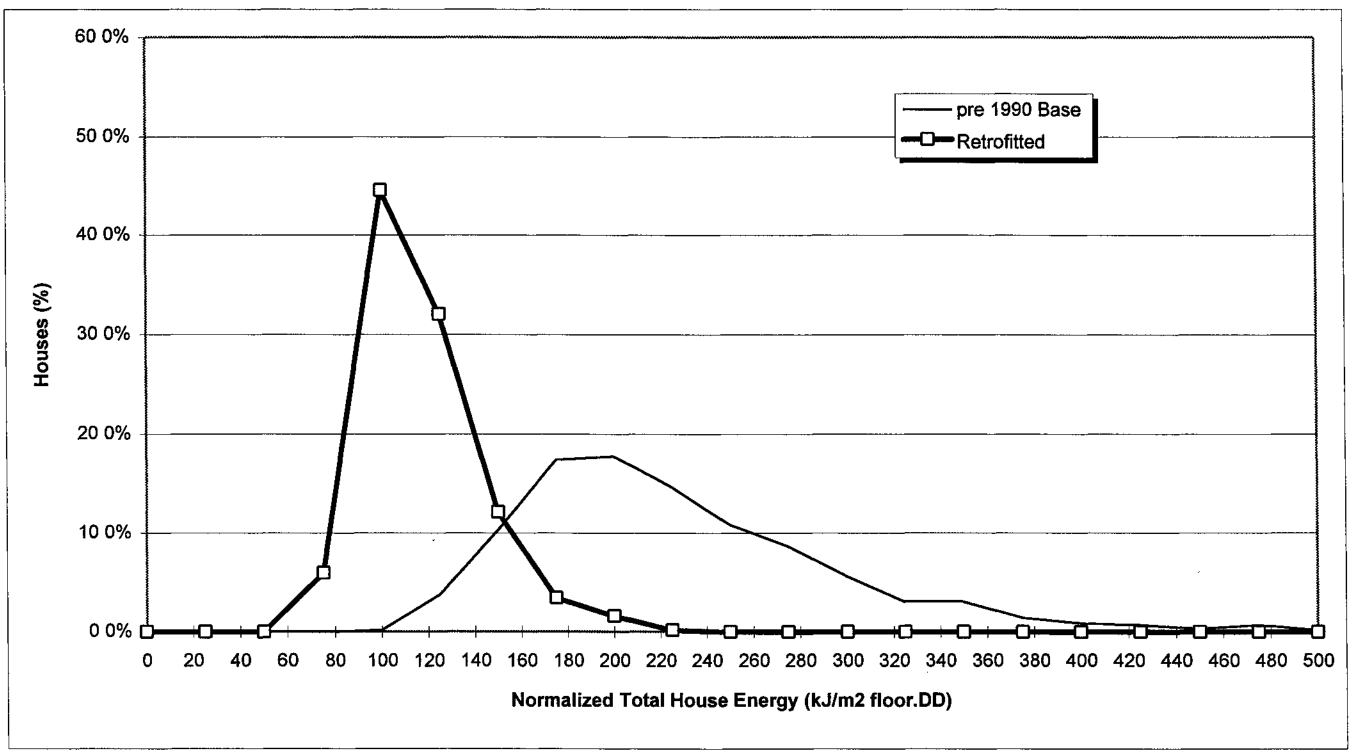
Note:
Results are for 552 houses
(unweighted by region or age)

Base Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	0	0 0%	50 to 75	0	0 0%
100	1	0 2%	75 to 100	1	0 2%
125	22	4 0%	100 to 125	21	3 8%
150	79	14 3%	125 to 150	57	10 3%
175	175	31 7%	150 to 175	96	17 4%
200	273	49 5%	175 to 200	98	17 8%
225	354	64 1%	200 to 225	81	14 7%
250	414	75 0%	225 to 250	60	10 9%
275	462	83 7%	250 to 275	48	8 7%
300	493	89 3%	275 to 300	31	5 6%
325	510	92 4%	300 to 325	17	3 1%
350	527	95 5%	325 to350	17	3 1%
375	535	96 9%	350 to 375	8	1 4%
400	540	97 8%	375 to 400	5	0 9%
425	544	98 6%	400 to 425	4	0 7%
450	546	98 9%	425 to 450	2	0 4%
475	550	99 6%	450 to 475	4	0 7%
500	551	99 8%	475 to 500	1	0 2%
525	551	99 8%	500 to 525	0	0 0%
550	551	99 8%	525 to 550	0	0 0%
575	552	100 0%	550 to 575	1	0 2%
600	552	100 0%	575 to 600	0	0 0%
			Total	552	

Retrofitted Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	33	6 0%	50 to 75	33	6 0%
100	279	50 5%	75 to 100	246	44 6%
125	456	82 6%	100 to 125	177	32 1%
150	523	94 7%	125 to 150	67	12 1%
175	542	98 2%	150 to 175	19	3 4%
200	551	99 8%	175 to 200	9	1 6%
225	552	100 0%	200 to 225	1	0 2%
250	552	100 0%	225 to 250	0	0 0%
275	552	100 0%	250 to 275	0	0 0%
300	552	100 0%	275 to 300	0	0 0%
325	552	100 0%	300 to 325	0	0 0%
350	552	100 0%	325 to350	0	0 0%
375	552	100 0%	350 to 375	0	0 0%
400	552	100 0%	375 to 400	0	0 0%
425	552	100 0%	400 to 425	0	0 0%
450	552	100 0%	425 to 450	0	0 0%
475	552	100 0%	450 to 475	0	0 0%
500	552	100 0%	475 to 500	0	0 0%
525	552	100 0%	500 to 525	0	0 0%
550	552	100 0%	525 to 550	0	0 0%
575	552	100 0%	550 to 575	0	0 0%
600	552	100 0%	575 to 600	0	0 0%
			Total	552	



Canadian Single Detached Residential Retrofit Program

Run ID: **M12C01**

Assumptions:

Description: **Description:**

Retrofit Goal:	**MID**	()			Amortization period:	**30**	years
Impact:	**minimize Cost**				Present Worth Factor:	**18.0**	
	Main floor	Basement	Mechanical systems:		Retrofit if less than:	**$12.00**	/GJ equiv.
Interior finish:	**strip**	**strip**	Space heating	**upgrade**	(energy retrofit cost/life-cycle net energy)		
Exterior finish:	**strip**	**retain**	Domestic hot water:	**upgrade**			
Water consumption:	**10%**	reduction	Ventilation control:	**iaq_opt**	Max. Exterior wall (urban)		
Utilities consumption:	**10%**	reduction*		**no ventilation in summer**	**3.00** RSI added		

*(except with combustion heating & hydroelectric utilities)

Canadian Single Detached Housing Projections: Demolition rate = 8 % of new housing

New housing are all houses built after 1989; Old housing are not retrofitted pre-1989; Retrofits are accumulated totals to date.

Year	1989	1995	2000	2005	2010	2015	2020	2025	2030
Old housing	5,658,122	5,612,310	4,941,807	4,273,225	3,605,889	2,939,258	2,272,758	1,606,258	939,705
Retrofits	0	0	638,042	1,276,299	1,914,692	2,553,149	3,191,595	3,830,012	4,468,390
New Housing	0	545,032	927,472	1,281,787	1,616,794	1,939,932	2,258,948	2,576,003	2,892,128
Total Housing	5,658,122	6,157,342	6,507,320	6,831,311	7,137,375	7,432,339	7,723,301	8,012,272	8,300,223

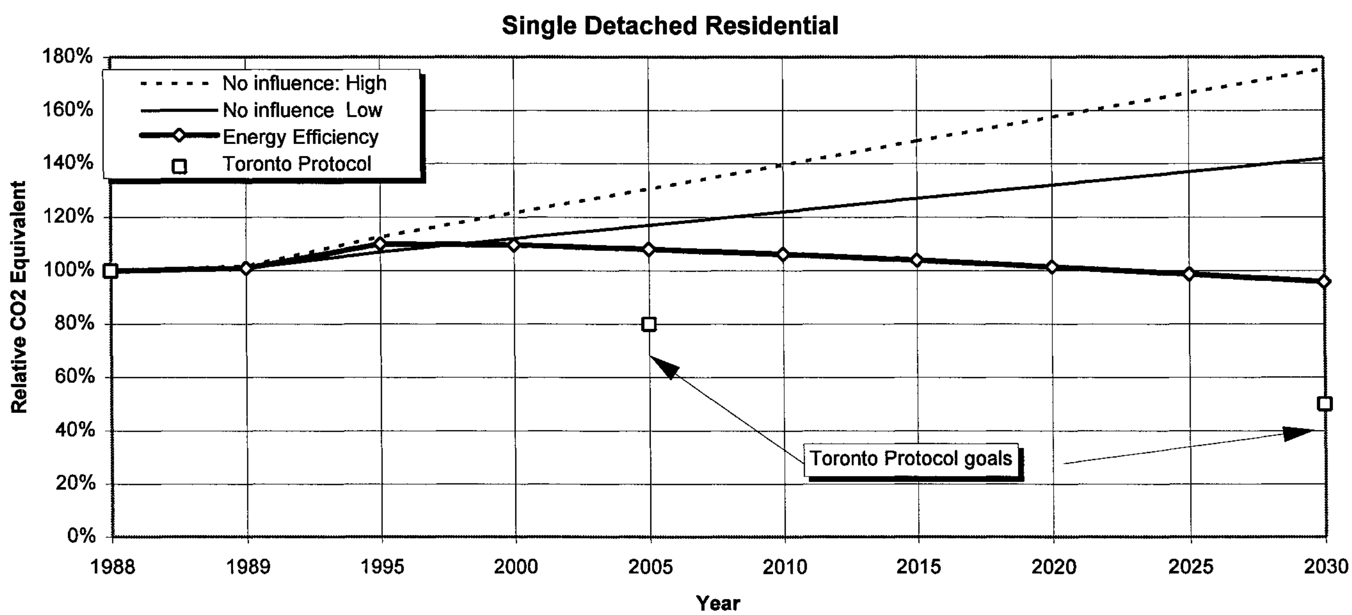
New Housing energy use and pollutant generation based on 1989 housing values, multiplied by:

Relative to 1989:	100%	90%	81%	73%	66%	59%	53%	48%	43%

Results:

82.1% of original (1989) housing stock had potential for retrofit, however only 78.4%of original stock were actually retrofitted

With full implementation of potential retrofits, 1989 housing stock would generate 61 1% as much CO2 (operations only)



Year	Energy Efficiency Option: Energy Retrofit Costs ($ 10^6/yr)	Total energy (source) (%)	Pollutant Generation due to Operation & Retrofits: CO2 (%)	CO (%)	NOx (%)	CH4 (%)	CO2 Equivalent (%)	Toronto Protocol Goals (%)	No Influence Options: Low est. CO2 Equivalent (%)	High est. CO2 Equivalent (%)
1988	0	100%	100%	100%	100%	100%	100%	**100%**	100%	100%
1989	0	101%	101%	101%	101%	101%	101%		101%	102%
1995	0	116%	109%	117%	104%	115%	110%		107%	113%
2000	919	116%	109%	122%	98%	117%	110%		112%	122%
2005	919	**115%**	107%	125%	92%	118%	**108%**	**80%**	**117%**	**131%**
2010	920	113%	105%	128%	86%	119%	106%		122%	140%
2015	920	112%	103%	130%	79%	119%	104%		127%	149%
2020	920	110%	100%	132%	73%	118%	101%		132%	158%
2025	920	108%	97%	134%	66%	117%	99%		137%	167%
2030	920	**105%**	**94%**	**135%**	**59%**	**116%**	**96%**	**50%**	**142%**	**176%**
2030		67%	62%	94%	48%	67%	**68%**	< Existing housing stock only		

Note: Energy Efficiency Option values calculated on basis of 1989 values, then adjusted by estimated increases from 1988 to 1989

Retrofit of Canadian Houses: MID Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: M12C01

Base

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:	
Space heating:	upgrade
Domestic hot water:	upgrade
Ventilation control: iaq_opt	

Operations:		
DHW:	10%	reduction
Utilities:	10%	reduction

		Number	Volume	Floor area	Natural air change		Total air change		Ventilation	Interior retrofits: Ventilation		Walls	
Region	Age	of Houses Retrofitted	(m^3)	(incl bsmt) (m^2)	Base ac/h	Upgrade ac/h	Base ac/h	Upgrade ac/h	more than 0.4 ac/h	less than 0.25 ac/h**	% of stock	Base RSI	Upgrade RSI
B C	<1921	9	478	186	0 70	0 34	0 70	0 36	20%	0%	0%	1 27	3 11
	1921-45	18	458	170	0 60	0 44	0 60	0 45	41%	0%	0%	1 45	2 78
	1946-60	24	441	166	0 53	0 39	0 53	0 41	26%	0%	0%	1 81	2 94
	1961-70	20	514	189	0 44	0 34	0 44	0 36	17%	0%	0%	1 97	3 00
	1971-80	10	553	202	0 39	0 34	0 39	0 36	19%	0%	0%	2 20	2 85
	>1981	20	687	267	0 21	0 21	0 53	0 27	0%	0%	0%	2 35	2 48
Prairies	<1921	11	407	153	0 54	0 24	0 54	0 29	0%	0%	0%	2 06	3 28
	1921-45	16	369	138	0 47	0 24	0 47	0 30	6%	0%	0%	2 10	3 21
	1946-60	41	417	157	0 31	0 19	0 31	0 28	2%	0%	0%	1 98	3 27
	1961-70	43	495	183	0 27	0 18	0 27	0 27	2%	0%	0%	2 12	3 24
	1971-80	27	485	188	0 20	0 16	0 20	0 27	0%	0%	0%	2 33	3 35
	>1981	38	593	223	0 22	0 14	0 44	0 26	0%	0%	0%	3 62	3 65
Ontario	<1921	14	520	188	0 78	0 38	0 78	0 41	43%	0%	100%	1 43	3 02
	1921-45	19	416	152	0 61	0 32	0 61	0 35	11%	0%	95%	1 49	2 82
	1946-60	52	507	191	0 37	0 26	0 37	0 31	11%	0%	0%	1 71	2 77
	1961-70	24	529	199	0 33	0 24	0 33	0 29	4%	0%	0%	2 05	3 10
	1971-80	17	475	183	0 28	0 28	0 28	0 32	0%	0%	0%	2 21	2 83
	>1981	34	847	305	0 19	0 17	0 24	0 26	0%	0%	0%	2 55	3 32
Quebec	<1921	7	506	192	0 60	0 32	0 60	0 34	14%	0%	0%	2 72	3 71
	1921-45	11	442	167	0 54	0 28	0 54	0 31	9%	0%	0%	2 01	3 23
	1946-60	46	476	180	0 40	0 24	0 40	0 29	4%	0%	0%	1 96	3 13
	1961-70	23	451	180	0 32	0 20	0 32	0 26	0%	0%	0%	2 28	3 43
	1971-80	18	441	164	0 28	0 19	0 28	0 26	0%	0%	0%	2 43	3 50
	>1981	2	471	193	0 15	0 20	0 15	0 27	0%	0%	0%	3 64	5 09
Maritimes	<1921	3	367	139	0 79	0 57	0 79	0 58	33%	0%	0%	2 50	3 23
	1921-45	5	338	127	0 89	0 64	0 89	0 65	80%	0%	0%	2 08	3 08
	1946-60	11	433	163	0 60	0 38	0 60	0 40	27%	0%	0%	1 90	3 17
	1961-70	14	470	177	0 49	0 27	0 49	0 30	7%	0%	0%	1 79	3 28
	1971-80	29	463	178	0 37	0 23	0 37	0 28	3%	0%	0%	2 25	3 37
	>1981	10	625	239	0 17	0 16	0 44	0 25	0%	0%	0%	3 70	3 90
CANADA	<1921	44	455	172	0 68	0 37	0 68	0 40	28%	0%	44%	2 00	3 27
	1921-45	69	405	151	0 62	0 38	0 62	0 41	21%	0%	34%	1 83	3 02
	1946-60	174	455	171	0 44	0 29	0 44	0 34	11%	0%	0%	1 87	3 06
	1961-70	124	492	185	0 37	0 24	0 37	0 30	5%	0%	0%	2 04	3 21
	1971-80	101	483	183	0 30	0 24	0 30	0 30	4%	0%	0%	2 28	3 18
	>1981	104	644	245	0 19	0 18	0 36	0 26	0%	0%	0%	3 17	3 69
	Total:	**616**											
	Average:*		489	185	0 43	0 28	0 46	0 33	10%	0%	9%	2 20	3 24

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Retrofit of Canadian Houses: MID Scenario

Cutoff for retrofit:
$12.00 /GJ equiv

Base

Region	Age	Ceiling Base RSI	Ceiling Upgrade RSI	Above grade Bsmt Base RSI	Above grade Bsmt Upgrade RSI	Windows (south) Base RSI	Windows (south) Upgrade RSI	Window /floor area %	Energy Related Costs Retrofit Unit Cost $	Energy Related Costs Total Cost (10^6 $)	Life cycle Unit Energy Cost ($/GJ/30y)
B C	<1921	1 88	7 24	0 91	2 98	0 26	0 37	9%	11,615	315	6 67
	1921-45	3 05	6 44	0 84	3 07	0 26	0 35	10%	8,924	782	8 23
	1946-60	3 72	6 89	1 13	2 89	0 28	0 35	14%	10,156	1,300	8 06
	1961-70	3 41	7 07	1 37	2 83	0 28	0 37	13%	9,712	894	8 71
	1971-80	3 53	6 61	1 35	2 77	0 29	0 38	14%	9,143	1,209	8 60
	>1981	4 60	6 10	1 17	2 71	0 36	0 36	12%	4,618	571	4 41
									Subtotal:	**5,073**	
Prairies	<1921	3 38	7 25	0 64	3 13	0 37	0 42	8%	8,895	987	5 00
	1921-45	3 62	7 32	0 56	3 22	0 36	0 42	8%	8,555	1,442	5 98
	1946-60	3 98	7 16	0 95	3 02	0 37	0 42	8%	8,578	2,351	6 77
	1961-70	3 24	6 59	0 95	2 94	0 35	0 40	8%	8,094	1,327	6 84
	1971-80	3 58	6 93	1 35	2 79	0 36	0 42	9%	9,071	1,571	8 17
	>1981	6 96	7 06	1 88	2 88	0 49	0 50	7%	2,406	349	2 70
									Subtotal:	**8,026**	
Ontario	<1921	3 37	7 29	0 65	3 19	0 35	0 40	9%	10,857	3,187	4 11
	1921-45	4 24	7 12	0 72	3 05	0 36	0 40	10%	7,925	1,935	5 28
	1946-60	4 11	6 74	0 75	3 03	0 37	0 40	10%	8,306	4,111	7 54
	1961-70	3 62	6 74	0 91	2 96	0 37	0 40	11%	8,696	2,175	8 40
	1971-80	3 98	6 26	1 35	2 82	0 35	0 38	11%	6,362	1,276	8 13
	>1981	5 69	5 91	1 44	2 45	0 36	0 38	8%	5,604	1,653	6 79
									Subtotal:	**14,337**	
Quebec	<1921	2 94	9 00	0 99	2 83	0 38	0 39	6%	8,625	1,103	7 13
	1921-45	3 68	9 00	0 90	3 11	0 38	0 40	8%	9,158	849	5 09
	1946-60	4 23	9 00	1 07	2 93	0 37	0 39	9%	9,108	2,055	6 27
	1961-70	3 67	9 00	1 31	2 71	0 37	0 39	11%	9,536	1,309	8 37
	1971-80	3 77	8 90	1 39	2 72	0 37	0 39	11%	9,067	1,327	8 72
	>1981	5 84	9 00	1 92	2 87	0 39	0 37	14%	7,725	76	9 78
									Subtotal:	**6,720**	
Maritimes	<1921	2 54	7 20	1 19	2 71	0 33	0 43	11%	7,441	777	4 50
	1921-45	1 73	7 92	0 92	3 01	0 35	0 37	9%	8,096	580	4 64
	1946-60	3 07	8 51	0 82	3 03	0 35	0 38	9%	9,010	1,048	4 69
	1961-70	2 89	8 87	0 89	2 95	0 36	0 38	9%	8,961	698	5 40
	1971-80	3 27	8 57	1 33	2 78	0 35	0 39	10%	9,202	995	7 45
	>1981	6 14	9 00	2 50	3 03	0 37	0 38	8%	1,992	112	1 55
									Subtotal:	**4,211**	
CANADA	<1921	2 82	7 60	0 88	2 97	0 34	0 40	9%	9,487	6,369	5 48
	1921-45	3 26	7 56	0 79	3 09	0 34	0 39	9%	8,532	5,588	5 84
	1946-60	3 82	7 66	0 95	2 98	0 35	0 39	10%	9,032	10,865	6 67
	1961-70	3 36	7 65	1 08	2 88	0 35	0 39	11%	9,000	6,403	7 54
	1971-80	3 62	7 45	1 35	2 78	0 34	0 39	11%	8,569	6,379	8 21
	>1981	5 85	7 41	1 78	2 79	0 39	0 40	10%	4,469	2,761	5 05
	Total:								**Total:**	**38,366**	
	Average:	3 79	7 56	1 14	2 91	0 35	0 39	10%	**$8,181** (unweighted)		6 47

Notes:
* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Retrofit of Canadian Houses: MID Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Retrofit rules: MID scenario (), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 10% reduction
Utilities: 10% reduction*
*(except with combustion heating & hydroelectric utilities)

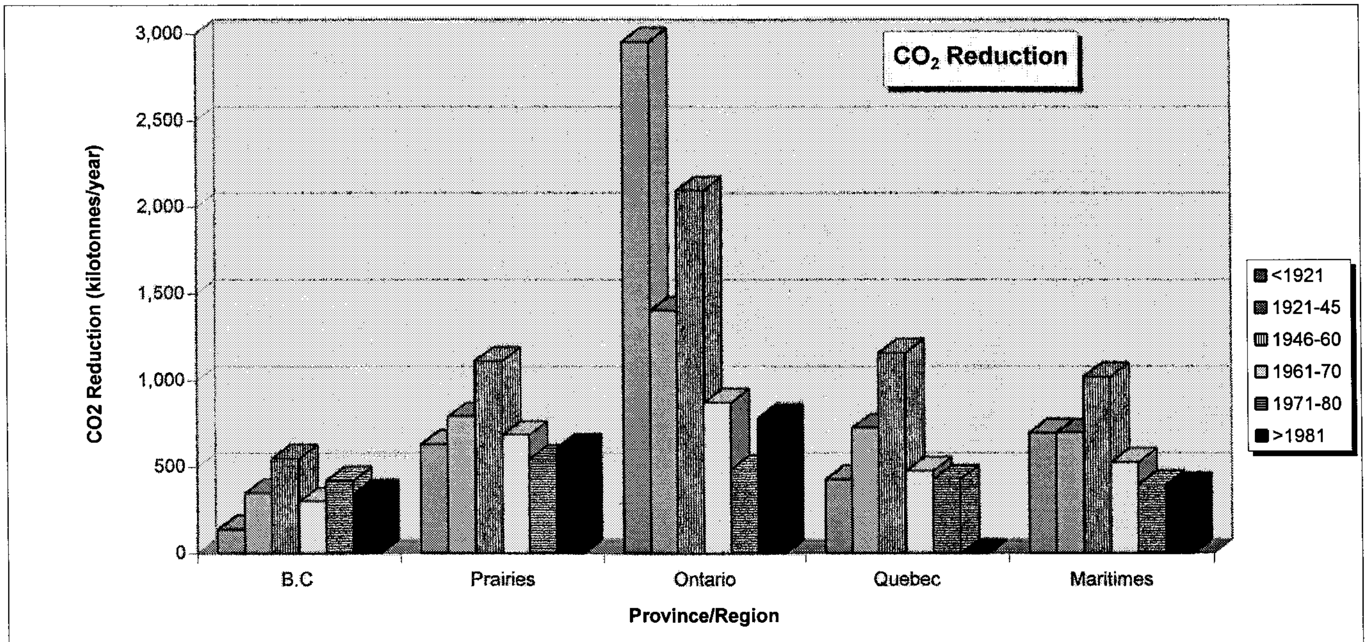
Min. upgrade:	RSI	
Walls	0 50	added
Windows	0 10	added

Mechanical systems:
Space heating: upgrade — Ventilation control: iaq_opt
Domestic hot water: upgrade — no ventilation in summer

Cutoff for retrofit: **$12.00** /GJ equiv
Run ID: M12C01
Base

Max. Exterior (urban): 3 00 RSI added

Age	Housing Stock	B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction	CH4 Reduction	CO Reduction	NOx Reduction
		CO_2 reduction - Operation only (kilotonnes/yr)					(kilotonnes/yr)		(kilotonnes/yr)	(kilotonnes/yr)	(kilotonnes/yr)
<1921	666,980	142	631	2,955	428	697	**4,853**	51%	0.03	0.33	40.2
1921-45	684,173	351	791	1,404	724	697	**3,967**	50%	0.03	-0.03	32.9
1946-60	1,356,041	549	1,111	2,095	1,157	1,021	**5,933**	43%	0.05	-0.01	44.9
1961-70	875,044	302	685	872	477	527	**2,862**	36%	0.03	0.10	18.3
1971-80	1,156,834	420	545	487	430	397	**2,279**	26%	0.03	0.19	9.5
>1981	919,050	346	608	781	1	384	**2,120**	26%	0 04	0 20	2 8
Total	5,658,122	2,109	4,371	8,595	3,217	3,723	**22,014**	**39%**	0.22	0.79	148.6



Age	Housing Stock	CO_2 (kilotonnes)	payback (years)	CH4 (kilotonnes)	payback (years)	CO (kilotonnes)	payback (years)	NOx (kilotonnes)	payback (years)	Used (PJ)	Payback (years)
		RETROFIT EMBODIED: POLLUTANTS								RETROFIT ENERGY	
<1921	666,980	1,245	0.3	0.03	0.8	2.0	6.1	3.4	0.1	34.7	0.4
1921-45	684,173	1,084	0.3	0.02	0.8	2.0	neg.	2.9	0.1	30.5	0.5
1946-60	1,356,041	2,181	0.4	0.04	0.8	3.2	neg.	5.3	0.1	63.5	0.6
1961-70	875,044	1,291	0.5	0.03	0.8	1.9	17.8	3.2	0.2	37.9	0.7
1971-80	1,156,834	1,299	0.6	0.03	0.8	1.8	9.9	3.2	0.3	36.6	0.7
>1981	919,050	714	0 3	0 01	0 3	1 6	8 0	1 8	0.6	20.9	0 5
Total	5,658,122	7,814	0.4	0.16	0.7	12.5	15.9	19.9	0.1	224	0.6

Retrofit of Canadian Houses: MID Scenario

Simulations using REES version 1 20

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: M12C01

Base

Impact: minimize Cost

DHW: 10% reduction

Utilities: 10% reduction*

*(except with combustion heating & hydroelectric utilities)

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Retrofit rules: MID scenario (), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Min. upgrade:	RSI
Walls	0 50
Windows	0 10

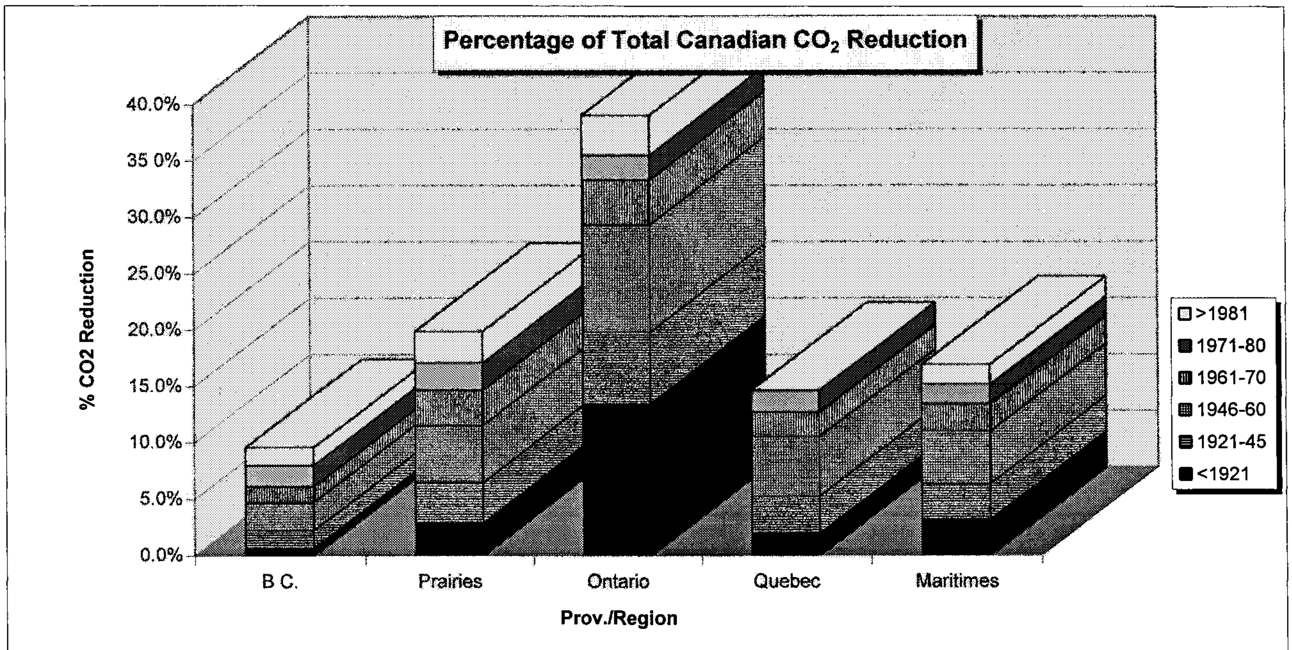
Max. Exterior (urban)	
3 00	RSI

Mechanical systems:

Space heating:	upgrade	Ventilation control: iaq_opt
Domestic hot water:	upgrade	no ventilation in summer

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Age	Housing Stock	% of Total Canadian CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction (kilotonnes/yr)	(%)	Energy Savings (PJ/year)	(%)
<1921	666,980	0.6%	2.9%	13.4%	1.9%	3.2%	**22.0%**	4,853	51%	80.8	46%
1921-45	684,173	1.6%	3.6%	6.4%	3.3%	3.2%	**18.0%**	3,967	50%	62.7	44%
1946-60	1,356,041	2.5%	5.0%	9.5%	5.3%	4.6%	**26.9%**	5,933	43%	100.5	38%
1961-70	875,044	1.4%	3.1%	4.0%	2.2%	2.4%	**13.0%**	2,862	36%	53.3	32%
1971-80	1,156,834	1.9%	2.5%	2.2%	2.0%	1.8%	**10.4%**	2,279	26%	50.8	24%
>1981	919,050	1 6%	2 8%	3.5%	0.0%	1.7%	**9.6%**	2,120	26%	41 3	22%
Total	5,658,122	9.6%	19.9%	39.0%	14.6%	16.9%	**100.0%**	22,014	**39%**	389.3	**34%**



Age	Housing Stock	Retrofit (%)	ENERGY RELATED RETROFIT COSTS B.C. (10^6 $)	Prairies (10^6 $)	Ontario (10^6 $)	Quebec (10^6 $)	Maritimes (10^6 $)	Canada (10^6 $)	Canada Total Cost (10^6 $)
<1921	666,980	98%	315	987	3,187	1,103	777	6,369	12,492
1921-45	684,173	95%	782	1,442	1,935	849	580	5,588	11,692
1946-60	1,356,041	90%	1,300	2,351	4,111	2,055	1,048	10,865	23,786
1961-70	875,044	82%	894	1,327	2,175	1,309	698	6,403	14,084
1971-80	1,156,834	69%	1,209	1,571	1,276	1,327	995	6,379	13,705
>1981	919,050	67%	571	349	1,653	76	112	2,761	7,365
Total	5,658,122	82%	**5,073**	**8,026**	**14,337**	**6,720**	**4,211**	**38,366**	**83,124**

Normalized Total Energy Use (Existing Single-Detached Houses) for MID Scenario

Base

Run ID: M12C01

Impact: **minimize Cost**

Cutoff for retrofit:	**$12.00**	/GJ equiv
Houses retrofitted:	82%	of total
Energy reduction:	34%	of total **source** use

	Base	Retrofitted	
Average	**211**	**120**	kJ/m^2DD
Minimum	93	62	kJ/m^2DD
Maximum	553	247	kJ/m^2DD

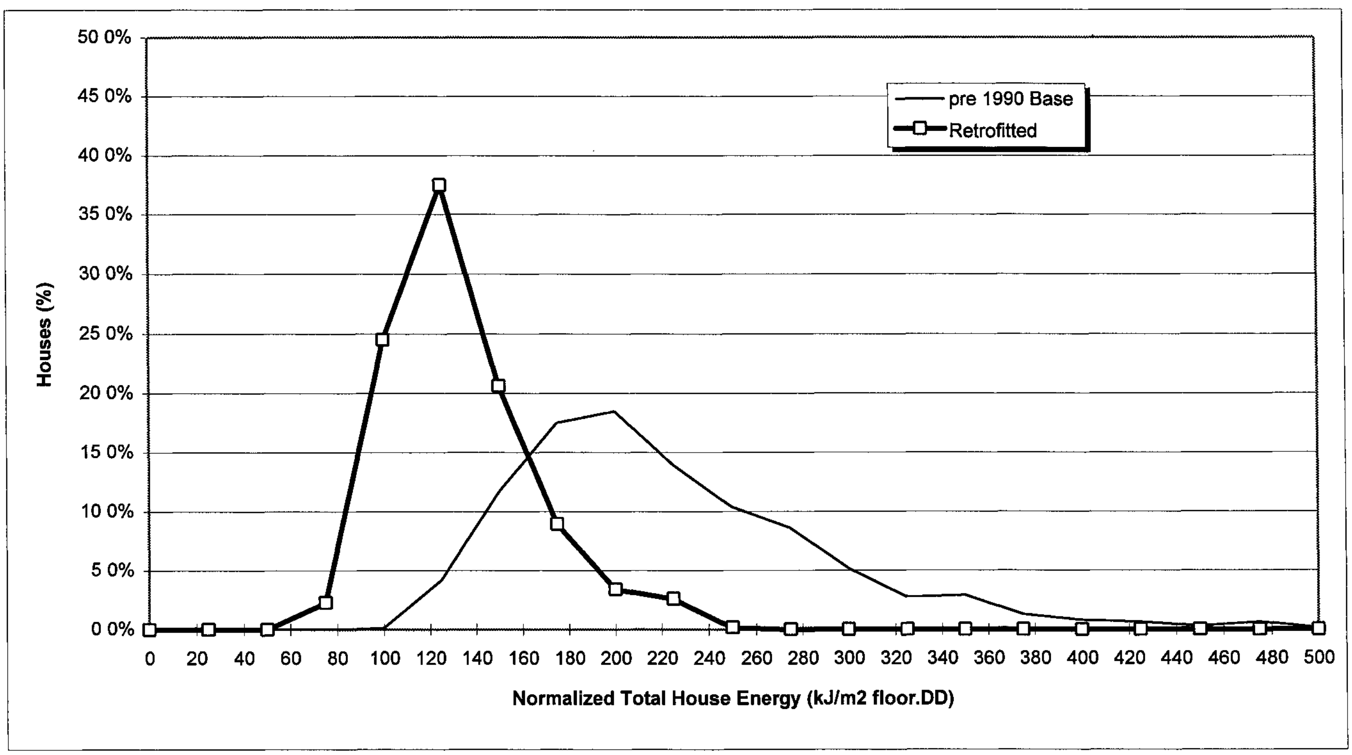
Note:
Results are for 616 houses
(unweighted by region or age)

Base Single-Detached

Energy use Threshold kJ/m^2DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m^2DD	Houses no.	%
0	0	0.0%	0	0	0.0%
25	0	0.0%	0 to 25	0	0.0%
50	0	0.0%	25 to 50	0	0.0%
75	0	0.0%	50 to 75	0	0.0%
100	1	0.2%	75 to 100	1	0.2%
125	27	4.4%	100 to 125	26	4.2%
150	99	16.1%	125 to 150	72	11.7%
175	207	33.6%	150 to 175	108	17.5%
200	321	52.1%	175 to 200	114	18.5%
225	407	66.1%	200 to 225	86	14.0%
250	471	76.5%	225 to 250	64	10.4%
275	524	85.1%	250 to 275	53	8.6%
300	556	90.3%	275 to 300	32	5.2%
325	573	93.0%	300 to 325	17	2.8%
350	591	95.9%	325 to350	18	2.9%
375	599	97.2%	350 to 375	8	1.3%
400	604	98.1%	375 to 400	5	0.8%
425	608	98.7%	400 to 425	4	0.6%
450	610	99.0%	425 to 450	2	0.3%
475	614	99.7%	450 to 475	4	0.6%
500	615	99.8%	475 to 500	1	0.2%
525	615	99.8%	500 to 525	0	0.0%
550	615	99.8%	525 to 550	0	0.0%
575	616	100.0%	550 to 575	1	0.2%
600	616	100.0%	575 to 600	0	0.0%
			Total	616	

Retrofitted Single-Detached

Energy use Threshold kJ/m^2DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m^2DD	Houses no.	%
0	0	0.0%	0	0	0.0%
25	0	0.0%	0 to 25	0	0.0%
50	0	0.0%	25 to 50	0	0.0%
75	14	2.3%	50 to 75	14	2.3%
100	165	26.8%	75 to 100	151	24.5%
125	396	64.3%	100 to 125	231	37.5%
150	523	84.9%	125 to 150	127	20.6%
175	578	93.8%	150 to 175	55	8.9%
200	599	97.2%	175 to 200	21	3.4%
225	615	99.8%	200 to 225	16	2.6%
250	616	100.0%	225 to 250	1	0.2%
275	616	100.0%	250 to 275	0	0.0%
300	616	100.0%	275 to 300	0	0.0%
325	616	100.0%	300 to 325	0	0.0%
350	616	100.0%	325 to350	0	0.0%
375	616	100.0%	350 to 375	0	0.0%
400	616	100.0%	375 to 400	0	0.0%
425	616	100.0%	400 to 425	0	0.0%
450	616	100.0%	425 to 450	0	0.0%
475	616	100.0%	450 to 475	0	0.0%
500	616	100.0%	475 to 500	0	0.0%
525	616	100.0%	500 to 525	0	0.0%
550	616	100.0%	525 to 550	0	0.0%
575	616	100.0%	550 to 575	0	0.0%
600	616	100.0%	575 to 600	0	0.0%
			Total	616	



Canadian Single Detached Residential Retrofit Program

Run ID: **L12C01**

Assumptions:

Description: **Description:**

Retrofit Goal: **LOW** ()

Impact: **minimize Cost**

Amortization period: **30** years

Present Worth Factor: **18.0**

Retrofit if less than: **$12.00** /GJ equiv
(energy retrofit cost/life-cycle net energy)

	Main floor	Basement
Interior finish:	**strip**	**strip**
Exterior finish:	**strip**	**retain**
Water consumption:	**0%**	reduction
Utilities consumption:	**0%**	reduction*

*(except with combustion heating & hydroelectric utilities)

Mechanical systems:	
Space heating:	**upgrade**
Domestic hot water:	**upgrade**
Ventilation control:	**iaq_opt**
	no ventilation in summer

Max. Exterior wall (urban)
3.00 RSI added

Canadian Single Detached Housing Projections: Demolition rate = 8.% of new housing

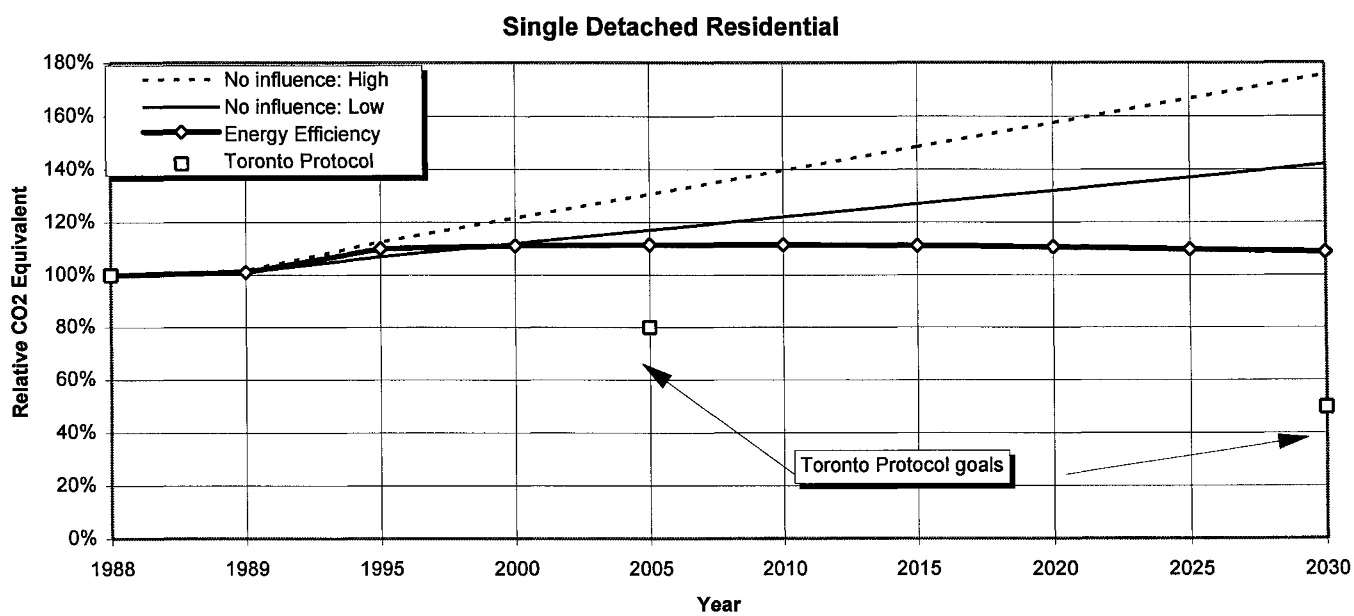
New housing are all houses built after 1989; Old housing are not retrofitted pre-1989; Retrofits are accumulated totals to date.

Year	1989	1995	2000	2005	2010	2015	2020	2025	2030
Old housing	5,658,122	5,612,310	4,894,341	4,178,277	3,463,449	2,749,321	2,035,324	1,321,330	607,286
Retrofits	0	0	685,508	1,371,248	2,057,132	2,743,086	3,429,029	4,114,939	4,800,809
New Housing	0	545,032	927,472	1,281,787	1,616,794	1,939,932	2,258,948	2,576,003	2,892,128
Total Housing	5,658,122	6,157,342	6,507,320	6,831,311	7,137,375	7,432,339	7,723,301	8,012,272	8,300,223
New Housing energy use and pollutant generation based on 1989 housing values, multiplied by:									
Relative to 1989:	100%	90%	81%	73%	66%	59%	53%	48%	43%

Results:

88.6% of original (1989) housing stock had potential for retrofit, however only 84.6%of original stock were actually retrofitted

With full implementation of potential retrofits, 1989 housing stock would generate 75 5% as much CO2 (operations only)



	Energy Efficiency Option:								No Influence Options:	
	Energy Retrofit Costs	Total energy (source)	Pollutant Generation due to Operation & Retrofits					Toronto Protocol Goals	Low est. CO2 Equivalent	High est. CO2 Equivalent
Year	($ 10^6/yr)	(%)	CO2 (%)	CO (%)	NOx (%)	CH4 (%)	CO2 Equivalent (%)	(%)	(%)	(%)
1988	0	100%	100%	100%	100%	100%	100%	**100%**	100%	100%
1989	0	101%	101%	101%	101%	101%	101%		101%	102%
1995	0	116%	109%	117%	104%	115%	110%		107%	113%
2000	395	117%	110%	123%	100%	118%	111%		112%	122%
2005	395	**118%**	111%	127%	97%	120%	**111%**	**80%**	**117%**	**131%**
2010	395	118%	110%	131%	93%	122%	111%		122%	140%
2015	395	118%	110%	135%	89%	123%	111%		127%	149%
2020	395	117%	109%	138%	86%	123%	111%		132%	158%
2025	395	117%	108%	141%	82%	124%	110%		137%	167%
2030	395	**116%**	**106%**	**144%**	**78%**	**123%**	**109%**	**50%**	**142%**	**176%**
2030		77%	74%	103%	66%	75%	**80%**	< Existing housing stock only		

Note: Energy Efficiency Option values calculated on basis of 1989 values, then adjusted by estimated increases from 1988 to 1989

Retrofit of Canadian Houses: LOW Scenario

Retrofitted houses only

Simulations using REES version 1 20

Impact: minimize Cost

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: L12C01

Base

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Mechanical systems:
Space heating: upgrade
Domestic hot water: upgrade
Ventilation control: iaq_opt

Operations:
DHW: 0% reduction
Utilities: 0% reduction

Region	Age	Number of Houses Retrofitted	Volume (m^3)	Floor area (incl bsmt) (m^2)	Natural air change Base ac/h	Natural air change Upgrade ac/h	Total air change Base ac/h	Total air change Upgrade ac/h	Ventilation more than 0.4 ac/h	Interior retrofits: Ventilation less than 0.25 ac/h**	Interior retrofits: % of stock	Walls Base RSI	Walls Upgrade RSI
B C	<1921	9	478	186	0 70	0 59	0 70	0 59	90%	0%	0%	1 27	2 14
	1921-45	20	458	172	0 60	0 55	0 60	0 56	86%	0%	0%	1 45	2 22
	1946-60	26	441	160	0 53	0 58	0 53	0 58	66%	0%	0%	1 81	2 20
	1961-70	21	514	191	0 44	0 49	0 44	0 49	72%	0%	0%	1 97	2 18
	1971-80	12	553	202	0 39	0 46	0 39	0 46	56%	0%	0%	2 20	2 18
	>1981	21	687	263	0 21	0 23	0 53	0 27	5%	0%	0%	2 35	2 36
Prairies	<1921	11	407	153	0 54	0 52	0 54	0 52	55%	0%	0%	2 06	2 28
	1921-45	16	369	138	0 47	0 52	0 47	0 52	69%	0%	0%	2 10	2 25
	1946-60	43	417	154	0 31	0 35	0 31	0 35	48%	0%	0%	1 98	2 20
	1961-70	47	495	183	0 27	0 30	0 27	0 30	12%	0%	0%	2 12	2 22
	1971-80	36	485	183	0 20	0 21	0 20	0 21	5%	0%	0%	2 33	2 36
	>1981	40	593	226	0 22	0 14	0 44	0 22	0%	0%	0%	3 62	3 62
Ontario	<1921	14	520	196	0 78	0 74	0 78	0 74	100%	0%	0%	1 43	1 51
	1921-45	17	416	159	0 61	0 59	0 61	0 59	89%	0%	0%	1 49	1 73
	1946-60	52	507	191	0 37	0 40	0 37	0 40	51%	0%	0%	1 71	1 86
	1961-70	25	529	196	0 33	0 38	0 33	0 38	32%	0%	0%	2 05	2 18
	1971-80	20	475	185	0 28	0 33	0 28	0 33	11%	0%	0%	2 21	2 39
	>1981	42	847	324	0 19	0 19	0 24	0 20	0%	0%	0%	2 55	2 55
Quebec	<1921	7	506	192	0 60	0 62	0 60	0 62	100%	0%	0%	2 72	2 77
	1921-45	11	442	167	0 54	0 59	0 54	0 59	100%	0%	0%	2 01	2 13
	1946-60	47	476	180	0 40	0 42	0 40	0 42	46%	0%	0%	1 96	2 08
	1961-70	25	451	174	0 32	0 35	0 32	0 35	10%	0%	0%	2 28	2 37
	1971-80	22	441	163	0 28	0 30	0 28	0 30	0%	0%	0%	2 43	2 47
	>1981	13	471	177	0 15	0 15	0 15	0 15	0%	0%	0%	3 64	3 92
Maritimes	<1921	3	367	139	0 79	0 86	0 79	0 86	100%	0%	0%	2 50	2 50
	1921-45	5	338	127	0 89	0 91	0 89	0 91	100%	0%	0%	2 08	2 42
	1946-60	10	433	157	0 60	0 58	0 60	0 58	91%	0%	0%	1 90	2 20
	1961-70	13	470	173	0 49	0 48	0 49	0 48	79%	0%	0%	1 79	2 18
	1971-80	30	463	177	0 37	0 38	0 37	0 38	24%	0%	0%	2 25	2 31
	>1981	13	625	237	0 17	0 16	0 44	0 25	0%	0%	0%	3 70	3 73
CANADA	<1921	44	455	173	0 68	0 67	0 68	0 67	92%	0%	0%	2 00	2 24
	1921-45	69	405	153	0 62	0 63	0 62	0 63	86%	0%	0%	1 83	2 15
	1946-60	178	455	168	0 44	0 46	0 44	0 47	55%	0%	0%	1 87	2 11
	1961-70	131	492	183	0 37	0 40	0 37	0 40	33%	0%	0%	2 04	2 23
	1971-80	120	483	182	0 30	0 33	0 30	0 34	17%	0%	0%	2 28	2 34
	>1981	129	644	245	0 19	0 17	0 36	0 22	1%	0%	0%	3 17	3 23
	Total:	**671**											
	Average:*		489	184	0 43	0 45	0 46	0 45	43%	0%	0%	2 20	2 38

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

** percentages less than 0 25 ac/h apply to interior retrofits only (next column)

Retrofit of Canadian Houses: LOW Scenario

Cutoff for retrofit: **$12.00** /GJ equiv

Base

Region	Age	Ceiling Base RSI	Ceiling Upgrade RSI	Above grade Bsmt Base RSI	Above grade Bsmt Upgrade RSI	Windows (south) Base RSI	Windows (south) Upgrade RSI	Window /floor area %	Energy Related Costs: Retrofit Unit Cost $	Energy Related Costs: Total Cost (10^6 $)	Life cycle Unit Energy Cost ($/GJ/30y)
B C	<1921	1 88	7 00	0 91	2 98	0 26	0 36	9%	6,965	189	5 39
	1921-45	3 05	7 04	0 84	3 02	0 26	0 35	10%	6,231	607	7 04
	1946-60	3 72	7 10	1 13	2 86	0 28	0 35	15%	6,172	856	6 84
	1961-70	3 41	7 04	1 37	2 89	0 28	0 36	14%	5,155	498	6 91
	1971-80	3 53	7 18	1 35	2 77	0 29	0 36	13%	4,862	772	7 01
	>1981	4 60	7 00	1 17	2 72	0 36	0 36	12%	2,765	359	3 47
									Subtotal:	**3,281**	
Prairies	<1921	3 38	6 58	0 64	3 13	0 37	0 38	8%	3,177	353	3 11
	1921-45	3 62	6 25	0 56	3 22	0 36	0 38	8%	3,151	531	3 86
	1946-60	3 98	6 51	0 95	2 98	0 37	0 38	8%	3,100	891	4 60
	1961-70	3 24	6 23	0 95	2 91	0 35	0 36	8%	3,056	548	4 95
	1971-80	3 58	6 41	1 35	2.77	0 36	0 36	9%	3,121	721	5 58
	>1981	6 96	7 05	1 88	2 84	0 49	0 49	7%	824	126	0 71
									Subtotal:	**3,169**	
Ontario	<1921	3 37	5 88	0 65	3 19	0 35	0 37	8%	3,559	1,044	3 69
	1921-45	4 24	6 20	0 72	3 13	0 36	0 37	9%	2,810	614	4 14
	1946-60	4 11	5 97	0 75	3 05	0 37	0 38	10%	3,468	1,717	5 99
	1961-70	3 62	5 96	0 91	2 94	0 37	0 38	12%	3,493	910	6 83
	1971-80	3 98	5 80	1 35	2 80	0 35	0 36	11%	3,389	800	6 80
	>1981	5 69	5 89	1 44	2 45	0 36	0 36	8%	1,238	451	2 30
									Subtotal:	**5,535**	
Quebec	<1921	2 94	5 80	0 99	2 83	0 38	0 38	6%	2,428	310	5 41
	1921-45	3 68	5 83	0 90	3 11	0 38	0 38	8%	3,076	285	3 40
	1946-60	4 23	5 97	1 07	2 92	0 37	0 37	9%	2,982	687	4 33
	1961-70	3 67	5 80	1 31	2 68	0 37	0 38	11%	3,211	479	6 25
	1971-80	3 77	5 92	1 39	2 69	0 37	0 37	11%	2,776	497	5 62
	>1981	5 84	6 38	1 92	2 34	0 39	0 40	11%	728	47	4 51
									Subtotal:	**2,306**	
Maritimes	<1921	2 54	7 20	1 19	2 71	0 33	0 38	11%	3,105	324	3 44
	1921-45	1 73	7 20	0 92	3 01	0 35	0 35	9%	4,176	299	3 40
	1946-60	3 07	7 20	0 82	3 11	0 35	0 35	9%	4,705	497	3 17
	1961-70	2 89	7 20	0 89	3 01	0 36	0 36	9%	3,731	270	3 25
	1971-80	3 27	7 20	1 33	2 79	0 35	0 36	10%	3,219	360	5 16
	>1981	6 14	7 20	2 50	3 05	0 37	0 37	9%	1,278	93	2 72
									Subtotal:	**1,845**	
CANADA	<1921	2 82	6 49	0 88	2 97	0 34	0 37	8%	3,847	2,221	4 21
	1921-45	3 26	6 50	0 79	3 10	0 34	0 37	9%	3,889	2,336	4 37
	1946-60	3 82	6 55	0 95	2 98	0 35	0 37	10%	4,086	4,649	4 99
	1961-70	3 36	6 45	1 08	2 89	0 35	0 37	11%	3,729	2,705	5 64
	1971-80	3 62	6 50	1 35	2 76	0 34	0 36	11%	3,473	3,149	6 03
	>1981	5 85	6 70	1 78	2 68	0 39	0 39	9%	1,367	1,076	2 74
	Total:								**Total:**	**16,136**	
	Average:	3 79	6 53	1 14	2 90	0 35	0 37	10%	**$3,398** (unweighted)		4 66

Notes:

* Cross-Canada statistics are not weighted by region or age category, except for percentages (ventilation and window/floor area)

Retrofit of Canadian Houses: LOW Scenario

Based on: Houses from STAR1 xls database
(single detached houses only; bsmt temp > 10C; ceiling area > 0)
Pollutant factors based on MatProp0 xls 2-Apr-93
(embodied factors use X-Canada elect source breakdown)
Housing statistics: Statistics Canada (Urban + Rural, single det) 1989

Retrofit rules: LOW scenario (), using Rule0 xls
Upgrade level selection based on space heating fuel type & location
Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Simulations using REES version 1 20
Impact: minimize Cost
DHW: 0% reduction
Utilities: 0% reduction*
*(except with combustion heating & hydroelectric utilities)

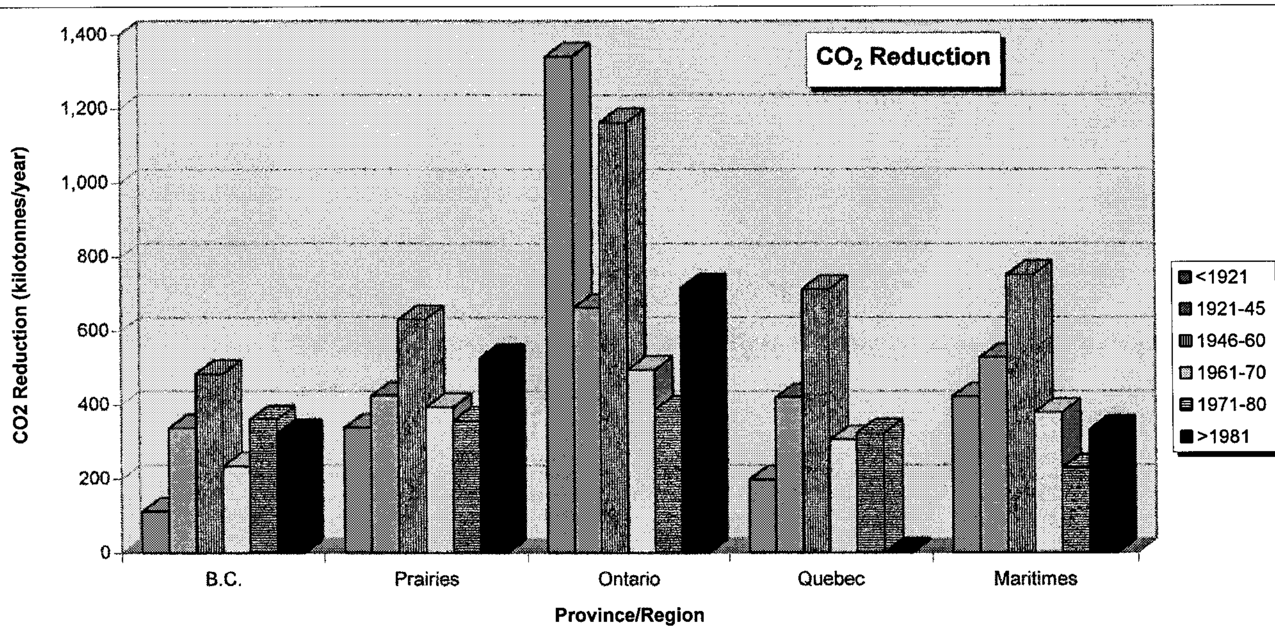
Min. upgrade:	RSI	
Walls	0 50	added
Windows	0 10	added

Mechanical systems:
Space heating: upgrade — Ventilation control: iaq_opt
Domestic hot water: upgrade — no ventilation in summer

Cutoff for retrofit: **$12.00** /GJ equiv
Run ID: L12C01
Base

Max. Exterior (urban): 3 00 RSI added

Age	Housing Stock	CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction	CH4 Reduction	CO Reduction	NOx Reduction
		(kilotonnes/yr)					(kilotonnes/yr)		(kilotonnes/yr)	(kilotonnes/yr)	(kilotonnes/yr)
<1921	666,980	112	338	1,341	198	423	**2,412**	25%	0.02	-0.08	20.5
1921-45	684,173	338	425	663	420	529	**2,374**	30%	0.02	-0.20	21.5
1946-60	1,356,041	484	631	1,163	713	753	**3,744**	27%	0.03	-0.33	30.2
1961-70	875,044	235	393	495	305	379	**1,807**	23%	0.02	-0.14	12.1
1971-80	1,156,834	360	357	386	324	229	**1,657**	19%	0.03	-0.04	6.6
>1981	919,050	323	527	717	2	333	**1,902**	23%	0 04	0.05	2 3
Total	5,658,122	1,852	2,672	4,766	1,961	2,646	**13,897**	**25%**	0.15	-0.74	93.3



Age	Housing Stock	RETROFIT EMBODIED: POLLUTANTS CO_2	payback	CH4	payback	CO	payback	NOx	payback	RETROFIT ENERGY Used	Payback
		(kilotonnes)	(years)	(kilotonnes)	(years)	(kilotonnes)	(years)	(kilotonnes)	(years)	(PJ)	(years)
<1921	666,980	339	0.1	0.01	0.4	0.8	neg.	0.9	0.0	8.8	0.2
1921-45	684,173	361	0.2	0.01	0.5	1.1	neg.	1.0	0.0	9.5	0.3
1946-60	1,356,041	670	0.2	0.01	0.4	1.9	neg.	1.9	0.1	18.0	0.3
1961-70	875,044	381	0.2	0.01	0.4	1.1	neg.	1.1	0.1	10.5	0.3
1971-80	1,156,834	504	0.3	0.01	0.4	1.1	neg.	1.4	0.2	13.3	0.4
>1981	919,050	172	0 1	0 00	0 1	1 0	18 9	0 6	0 2	6 1	0 2
Total	5,658,122	2,428	0.2	0.05	0.3	7.0	neg.	6.9	0.1	66	0.3

Retrofit of Canadian Houses: LOW Scenario

Simulations using REES version 1 20

Cutoff for retrofit: **$12.00** /GJ equiv

Run ID: L12C01

Base

Based on: Houses from STAR1 xls database

(single detached houses only; bsmt temp > 10C; ceiling area > 0)

Pollutant factors based on MatProp0 xls — 2-Apr-93

(embodied factors use X-Canada elect source breakdown)

Housing statistics: Statistics Canada (Urban + Rural, single det) — 1989

Retrofit rules: LOW scenario (), using Rule0 xls

Upgrade level selection based on space heating fuel type & location

Attic type ceilings assumed

	Main floor	Basement
Interior finish:	strip	strip
Exterior finish:	strip	retain

Impact: minimize Cost

DHW:	0%	reduction
Utilities:	0%	reduction*

*(except with combustion heating & hydroelectric utilities)

Min. upgrade:	RSI
Walls	0 50
Windows	0 10

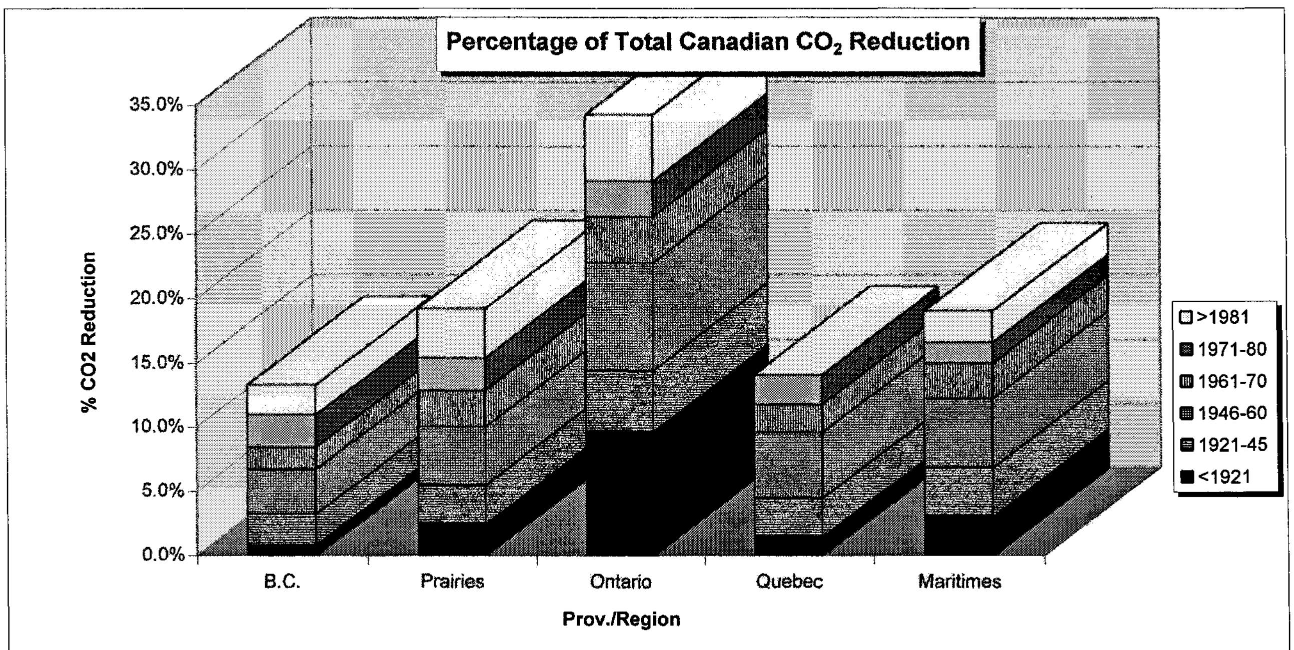
Max. Exterior (urban): 3 00 RSI

Mechanical systems:

Space heating:	upgrade	Ventilation control: iaq_opt
Domestic hot water:	upgrade	no ventilation in summer

Note: PJ = PetaJoule (= one million GJ or 278 million kWh)

Age	Housing Stock	% of Total Canadian CO_2 reduction - Operation only B.C.	Prairies	Ontario	Quebec	Maritimes	Canada	CO_2 Reduction (kilotonnes/yr)	(%)	Energy Savings (PJ/year)	(%)
<1921	666,980	0.8%	2.4%	9.7%	1.4%	3.0%	**17.4%**	2,412	25%	38.7	22%
1921-45	684,173	2.4%	3.1%	4.8%	3.0%	3.8%	**17.1%**	2,374	30%	35.7	25%
1946-60	1,356,041	3.5%	4.5%	8.4%	5.1%	5.4%	**26.9%**	3,744	27%	59.9	22%
1961-70	875,044	1.7%	2.8%	3.6%	2.2%	2.7%	**13.0%**	1,807	23%	32.3	19%
1971-80	1,156,834	2.6%	2.6%	2.8%	2.3%	1.7%	**11.9%**	1,657	19%	36.5	18%
>1981	919,050	2 3%	3 8%	5 2%	0 0%	2 4%	**13.7%**	1,902	23%	37 3	20%
Total	5,658,122	13.3%	19.2%	34.3%	14.1%	19.0%	**100.0%**	13,897	**25%**	240.4	**21%**



Age	Housing Stock	Retrofit (%)	ENERGY RELATED RETROFIT COSTS B.C. (10^6 $)	Prairies (10^6 $)	Ontario (10^6 $)	Quebec (10^6 $)	Maritimes (10^6 $)	Canada (10^6 $)	Canada Total Cost (10^6 $)
<1921	666,980	98%	189	353	1,044	310	324	2,221	4,648
1921-45	684,173	95%	607	531	614	285	299	2,336	5,219
1946-60	1,356,041	92%	856	891	1,717	687	497	4,649	10,362
1961-70	875,044	87%	498	548	910	479	270	2,705	6,099
1971-80	1,156,834	82%	772	721	800	497	360	3,149	7,016
>1981	919,050	83%	359	126	451	47	93	1,076	3,122
Total	5,658,122	89%	**3,281**	**3,169**	**5,535**	**2,306**	**1,845**	**16,136**	**36,467**

Normalized Total Energy Use (Existing Single-Detached Houses) for LOW Scenario

Base
Run ID: L12C01

Impact: **minimize Cost**

Cutoff for retrofit:	**$12.00**	/GJ equiv
Houses retrofitted:	89%	of total
Energy reduction:	21%	of total **source** use

	Base	Retrofitted	
Average	**204**	**148**	kJ/m²DD
Minimum	76	71	kJ/m²DD
Maximum	553	340	kJ/m²DD

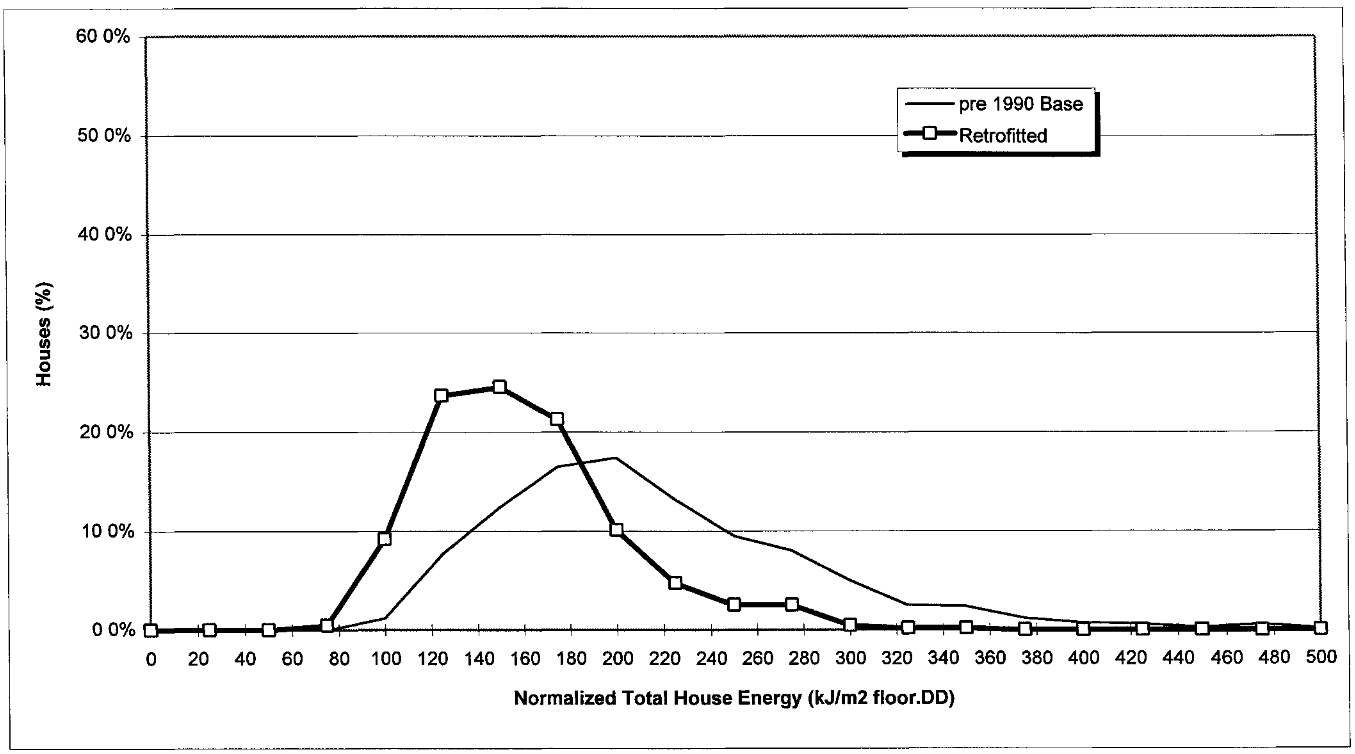
Note:
Results are for 671 houses
(unweighted by region or age)

Base Single-Detached

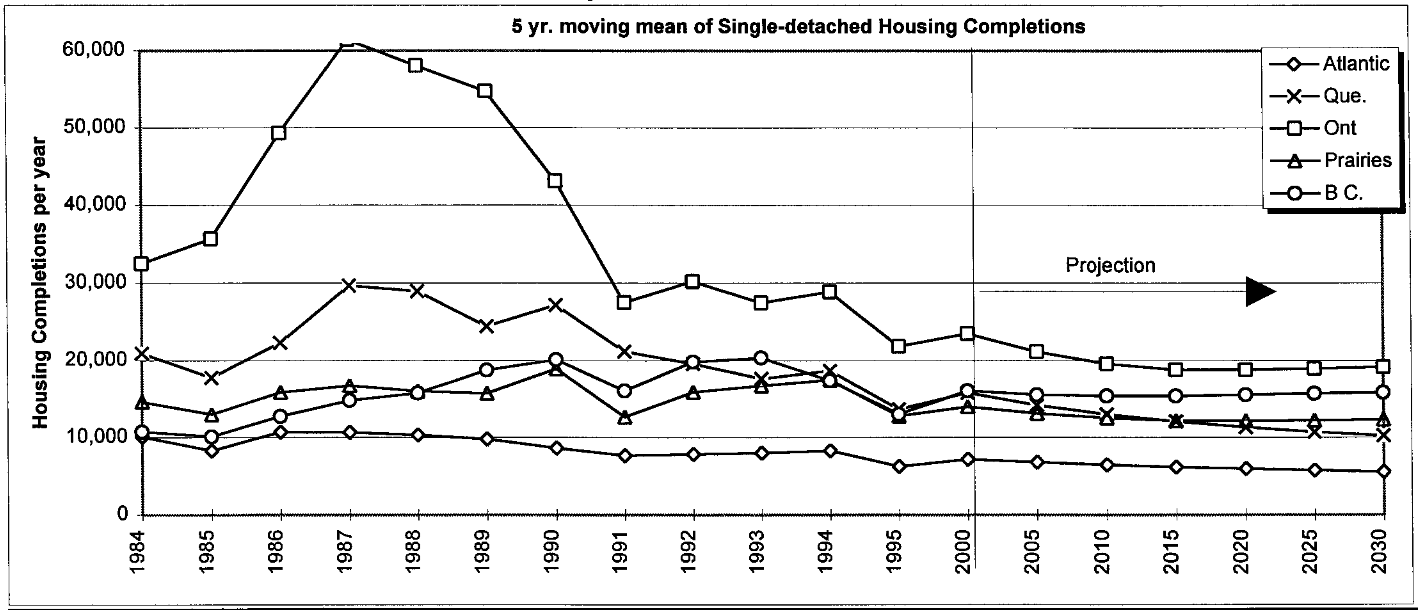
Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	0	0 0%	50 to 75	0	0 0%
100	8	1 2%	75 to 100	8	1 2%
125	60	8 9%	100 to 125	52	7 7%
150	144	21 5%	125 to 150	84	12 5%
175	255	38 0%	150 to 175	111	16 5%
200	372	55 4%	175 to 200	117	17 4%
225	461	68 7%	200 to 225	89	13 3%
250	525	78 2%	225 to 250	64	9 5%
275	579	86 3%	250 to 275	54	8 0%
300	613	91 4%	275 to 300	34	5 1%
325	630	93 9%	300 to 325	17	2 5%
350	646	96 3%	325 to350	16	2 4%
375	654	97 5%	350 to 375	8	1 2%
400	659	98 2%	375 to 400	5	0 7%
425	663	98 8%	400 to 425	4	0 6%
450	665	99 1%	425 to 450	2	0 3%
475	669	99 7%	450 to 475	4	0 6%
500	670	99 9%	475 to 500	1	0 1%
525	670	99 9%	500 to 525	0	0 0%
550	670	99 9%	525 to 550	0	0 0%
575	671	100 0%	550 to 575	1	0 1%
600	671	100 0%	575 to 600	0	0 0%
			Total	671	

Retrofitted Single-Detached

Energy use Threshold kJ/m²DD	Cumulative houses less than threshold no.	%	Normalized Energy use kJ/m²DD	Houses no.	%
0	0	0 0%	0	0	0 0%
25	0	0 0%	0 to 25	0	0 0%
50	0	0 0%	25 to 50	0	0 0%
75	3	0 4%	50 to 75	3	0 4%
100	65	9 7%	75 to 100	62	9 2%
125	224	33 4%	100 to 125	159	23 7%
150	389	58 0%	125 to 150	165	24 6%
175	532	79 3%	150 to 175	143	21 3%
200	600	89 4%	175 to 200	68	10 1%
225	632	94 2%	200 to 225	32	4 8%
250	649	96 7%	225 to 250	17	2 5%
275	666	99 3%	250 to 275	17	2 5%
300	669	99 7%	275 to 300	3	0 4%
325	670	99 9%	300 to 325	1	0 1%
350	671	100 0%	325 to350	1	0 1%
375	671	100 0%	350 to 375	0	0 0%
400	671	100 0%	375 to 400	0	0 0%
425	671	100 0%	400 to 425	0	0 0%
450	671	100 0%	425 to 450	0	0 0%
475	671	100 0%	450 to 475	0	0 0%
500	671	100 0%	475 to 500	0	0 0%
525	671	100 0%	500 to 525	0	0 0%
550	671	100 0%	525 to 550	0	0 0%
575	671	100 0%	550 to 575	0	0 0%
600	671	100 0%	575 to 600	0	0 0%
			Total	671	

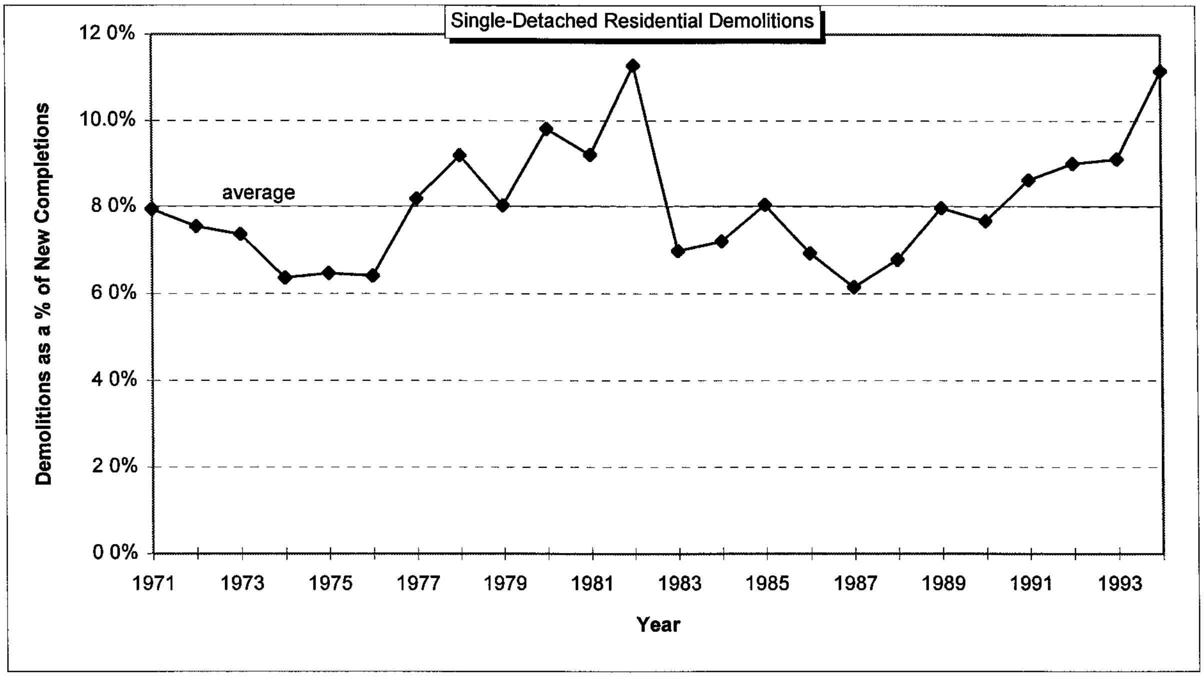


APPENDIX C.2 Single-Detached Housing Statistics



Year	Nlfd.	P.E.I.	N.S.	N.B.	Atlantic	Que.	Ont.	Man.	Sask.	Alta.	Prairies	B.C.	Canada
					5 yr moving growth (%/year)				(values for 2000 to 2030 are estimates)				
1989	2 9%	6 2%	-1 1%	-4 1%	-0 6%	2.9%	9 4%	-1 1%	-8.6%	6.7%	1.5%	12 4%	6.3%
1990	7 4%	-2 5%	-1 0%	-2.3%	0 6%	7 7%	2.9%	-1 1%	-13 6%	18 7%	7 7%	13 8%	5 7%
1991	1 4%	-11 2%	-9 1%	-7 6%	-6 0%	-0 9%	-8 2%	-12.3%	-22.1%	3.8%	-3 8%	4 1%	-4 2%
1992	-4 8%	-12 1%	-4 9%	-7 2%	-6 0%	-7.7%	-12.7%	-18 7%	-24 1%	8.8%	-1.0%	5 9%	-6 8%
1993	-10 2%	-7 6%	-1 8%	-4 0%	-5 2%	-9 4%	-14 3%	-14.4%	-14.2%	6 4%	0 9%	5.1%	-7 1%
1994	-13 6%	-3 0%	1 5%	-0 7%	-3 5%	-5.3%	-14 1%	-7 6%	-2.3%	4.5%	2 2%	-1 4%	-6.4%
1995	-11 8%	-0 8%	-3 6%	-4 8%	-5.8%	-13.0%	-13.5%	-13.9%	3.7%	-7.5%	-7.5%	-7.5%	-10 6%
2000					***-5.2%***	***-10.0%***	***-10.0%***				***-6.0%***	***-3.0%***	13.1%
2005					***-4.7%***	***-8.5%***	***-7.5%***				***-4.5%***	***-1.0%***	-7.4%
2010					***-4.2%***	***-7.2%***	***-4.0%***				***-3.0%***	***0.0%***	-5.4%
2015					***-3.8%***	***-6.1%***	***0.0%***				***0.0%***	***1.0%***	-3 5%
2020					***-3.4%***	***-5.2%***	***1.0%***				***0.5%***	***1.0%***	-1.3%
2025					***-3.1%***	***-4.4%***	***1.0%***				***1.0%***	***1.0%***	-0 6%
2030					***-2.8%***	***-3.8%***	***1.0%***				***1.0%***	***1.0%***	-0.3%

Year	Nlfd.	P.E.I.	N.S.	N.B.	Atlantic	Que.	Ont.	Man.	Sask.	Alta.	Prairies	B.C.	Canada
				Single Detached Housing Completions per year					(values for 2000 to 2030 are estimates)				
1984	2,861	351	3,483	3,411	10,106	20,927	32,480	3,484	2,876	8,231	14,591	10,771	88,875
1985	1,509	472	3,671	2,685	8,337	17,754	35,670	3,331	3,064	6,587	12,982	10,151	84,894
1986	2217	788	4475	3255	10,735	22322	49,268	4204	3624	8,022	15,850	12,727	110,902
1987	2521	728	4190	3222	10,661	29664	61,400	4935	3603	8,168	16,706	14,816	133,247
1988	2,961	678	3,597	3,111	10,347	28,980	58,072	3,916	2,525	9,586	16,027	15,785	129,211
1989	3,217	539	3,274	2,773	9,803	24456	54,732	3263	1523	10956	15,742	18,736	123,469
1990	2,434	391	3,473	2,332	8,630	27199	43,130	3109	1112	14699	18,920	20,111	117,990
1991	2402	438	2739	2136	7,715	21,190	27,499	1,810	884	9,967	12,661	16,072	85,137
1992	1869	392	3340	2244	7,845	19,590	30,193	1,744	1278	12873	15895	19,835	93,358
1993	1,647	493	3,302	2,602	8,044	17,618	27,470	1,925	1487	13295	16707	20,358	90,197
1994	1,649	471	3,517	2,690	8,327	18,675	28,876	2,365	1,377	13,728	17,470	17,383	90,731
1995	1,255	374	2,890	1,751	6,270	13,654	21,855	1,588	1,341	9,857	12,786	13,054	67,619
2000					*7,196*	*15,788*	*23,500*				*13,969*	*16,035*	*76,488*
2005					*6,819*	*14,209*	*21,150*				*13,131*	*15,554*	*70,863*
2010					*6,497*	*13,002*	*19,563*				*12,540*	*15,399*	*67,001*
2015					*6,222*	*12,062*	*18,781*				*12,164*	*15,399*	*64,628*
2020					*5,984*	*11,322*	*18,781*				*12,164*	*15,553*	*63,803*
2025					*5,779*	*10,731*	*18,969*				*12,225*	*15,708*	*63,411*
2030					*5,600*	*10,254*	*19,158*				*12,347*	*15,865*	*63,225*
average:													
1984-95	2,212	510	3,496	2,684	8,902	21,836	39,220	2,973	2,058	10,497	15,528	15,817	101,303
1991-95	1,764	434	3,158	2,285	7,640	18,145	27,179	1,886	1,273	11,944	15,104	17,340	85,408



Canada	A	B	C	D	E	F	G	H	I
					C/A			A - C	G - H
					Demolitions,			Complet.	
Year	Completions	5 yr avg.	Demolitions	5 yr avg.	% of complet.	Total stock	Increase	- Demos.	Residuals?
1971	56,757		4512		7 9%	3,750,144			
1972	106,508		8044		7.6%	3,835,747	85,603	98,464	-12,861
1973	122,696		9034		7 4%	3,934,026	98,279	113,662	-15,383
1974	129,704		8253		6.4%	4,038,191	104,165	121,451	-17,286
1975	113,409		7341		6.5%	4,128,734	90,543	106,068	-15,525
1976	128,623	120,188	8249	8,184	6 4%	4,278,345	149,611	120,374	29,237
1977	117,792		9656		8 2%	4,435,970	157,625	108,136	49,489
1978	106,195		9768		9 2%	4,575,040	139,070	96,427	42,643
1979	112,105		9012		8 0%	4,722,760	147,720	103,093	44,627
1980	90,720		8902		9.8%	4,838,617	115,857	81,818	34,039
1981	98,412	105,045	9067	9,281	9.2%	4,934,221	95,604	89,345	6,259
1982	54,720		6175		11.3%	4,977,519	43,298	48,545	-5,247
1983	95,320		6654		7.0%	5,058,260	80,741	88,666	-7,925
1984	88,875		6402		7.2%	5,133,666	75,406	82,473	-7,067
1985	84,894		6839		8.1%	5,206,271	72,605	78,055	-5,450
1986	110,902	86,942	7683	6,751	6.9%	5,322,402	116,131	103,219	12,912
1987	133,247		8193		6.1%	5,475,344	152,942	125,054	27,888
1988	129,211		8760		6 8%	5,622,452	147,108	120,451	26,657
1989	123,469		9855		8 0%	5,759,860	137,408	113,614	23,794
1990	117,990		9055		7 7%	5,889,212	129,352	108,935	20,417
1991	85,137	117,811	7346	8,642	8.6%	5,970,527	81,315	77,791	3,524
1992	93,358		8415		9 0%	6,055,846	85,319	84,943	376
1993	90,197		8223		9.1%	6,138,141	82,295	81,974	321
1994	90,731		10119		11.2%	6,219,051	80,910	80,612	298
Average	105,401		8,306		8 1%		107,344		10,249

1971-1994 Averages:							
	Completions	Average Demolitions	Regional Demo.Rate	Average Demo. Rate	1994 Stock	1994 Increase	1994 %Increase
PEI	658	6		0.8%	34,917	460	1 32%
Nfld.	2,667	110		4.8%	145,153	1,592	1 10%
NS	3,525	161		4 6%	236,680	3,358	1.42%
NB	3,279	130	4.0%	4 2%	195,283	2,598	1 33%
QU	23,324	1,055	4.9%	4 9%	1,283,240	17,244	1 34%
ON	35,109	2,741	8.3%	8 3%	2,288,142	26,127	1.14%
MA	3,463	394		12 9%	290,090	2,081	0 72%
SA	3,675	480		17 1%	291,281	1,141	0 39%
AB	12,865	821	8.5%	6 2%	626,251	13,257	2.12%
BC	16,849	2,396	14.3%	14 3%	809,742	12,754	1.58%

APPENDIX D Comparison with HOT-2000 (ver. 7)

			Design Loss W	Total Load GJ/y	Space Heat Internal GJ/y	Space Heat Solar GJ/y	Space Heat Demand GJ/y	Space Heat Fuel GJ/y	Space Heat Efficiency	Water Heat Load GJ/y	Water Heat Fuel GJ/y	Water Heat Efficiency
BC0020B	Pre 1920 archetype	HOT2000	13456	114 4	26 7	12 3	74 0	111 8	65%	9 7	21 3	46%
	Vancouver, B C	REES	11721	108.8	24.2	14.3	72.3	109.5	66%	9.1	16.9	54%
		Difference	-13%	-5%	-9%	16%	-2%	-2%		-7%	-21%	
BC0020U	Upgraded pre 1920 arch	HOT2000	6730	56 1	23 9	7 5	22 2	23 6	92%	7 8	10 5	74%
	Vancouver, B C	REES	6106	55.9	25.3	6.4	24.2	27.5	88%	7.3	8.3	88%
		Difference	-9%	0%	6%	-15%	9%	16%		-7%	-21%	
	Savings	HOT2000						88 1			10 8	
		REES						82.1			8.6	
		Difference						-7%			-21%	
BC8089B	1981-1989 archetype	HOT2000	11860	138 6	28 2	24 3	84 9	124 7	67%	16 2	28 6	56%
	Vancouver, B C	REES	10472	134.5	32.1	21.0	81.4	123.4	66%	15.1	27.9	54%
		Difference	-12%	-3%	13%	-14%	-4%	-1%		-7%	-2%	
BC8989U	Upgraded 1981-1989 arch	HOT2000	7186	84 0	28 7	18 2	35 7	38 0	92%	12 9	15 3	84%
	Vancouver, B C	REES	6922	84 5	30 9	15 9	37 7	42 9	88%	12 1	15 9	88%
		Difference	-4%	1%	8%	-13%	6%	13%		-7%	3%	
	Savings	HOT2000						86 7			13 3	
		REES						80.5			12.1	
		Difference						-7%			-9%	
PR0020B	Pre 1920 prairies archetype	HOT2000	14466	146 1	30 2	13 5	101 9	147 8	68%	12 9	25 2	51%
	Edmonton, AB	REES	12465	132.4	26.9	11.2	94.3	142.9	66%	12.1	22.4	54%
		Difference	-14%	-9%	-11%	-18%	-7%	-3%		-6%	-11%	
PR0020U	Upgraded pre 1920 arch	HOT2000	8621	87 8	20 8	11 7	54 9	58 5	92%	10 3	12 9	80%
	Edmonton, AB	REES	7700	82 2	26 4	8 8	47 0	53 4	88%	9 7	8 8	88%
		Difference	-11%	-6%	27%	-24%	-14%	-9%		-6%	-32%	
	Savings	HOT2000						89 3			12 3	
		REES						89.5			13.6	
		Difference						0%			11%	

Appendix E Outside Temperature Controlled (OTC) Ventilation

The critical periods, from an indoor air quality point of view, are usually in the spring and fall when the house is still closed up, since space heating is still required for most hours, however the temperature difference driven infiltration forces are relatively small. Therefore, natural infiltration is often very low and indoor pollutant concentrations (building and occupant generated) can rise above tolerable levels unless some form of ventilation is provided.

The following is a summary of a set of seven runs carried out on retrofitted houses in four of the climate zones.

For each OTC run, the difference between inside temperature and outside temperature (deltaT) above which the fans would be turned on was specified. The REES program calculated the number of hours and average outside temperature above and below the control set-point, then calculated total ventilation and energy use above the set-point (fans on) and below the set-point (fans off).

The following table compares several ventilation control scenarios, and shows house database row number, house ID, location, annual heating degree days, ventilation control, October to April average and minimum monthly total ventilation (including infiltration), OTC temperature difference (where applicable), house air-tightness, operating annual carbon dioxide production, annual space heating energy use, and life-cycle net energy cost (LCEC).

Five different ventilation systems were simulated for each house - continuous fans (with HRV), optimal control (with and without HRV), and OTC. The optimal control maintained approximately constant total air change for each month from October to April. The OTCavg case matched October to April average total air changes to the optimal case, while OTCmin matched the minimal monthly total air changes to the minimal monthly for the optimal case.

In all cases, the OTC runs resulted in operating carbon dioxide generation and space heat fuel use that was within -3% to +10% of the optimum (iaq_opt). The OTCavg usually had the lowest LCEC - indicating the most economic option, however minimum monthly total air change dropped to as low as 0.16 ac/h in some cases. These houses were sufficiently air-tight that the natural infiltration during cold months (fan off) was inadequate to maintain good air quality. A control that provides a constant minimum ventilation plus OTC may be necessary to avoid too low ventilation in tight houses.

VENTILATION SYSTEM CONTROLS

Comparison with other control strategies

DB number	House ID	Construction Date	Location	Degree Days DD18C	Ventilation Control	Avg. ACH Oct-Apr (ac/h)	Min ACH Oct-Apr (ac/h)	HRV?	deltaT OTC (C)	Wall Retrofit Type	Air-tight. (ac/h 50Pa)	Operating CO2 (kg/y)	SpHt.Fuel (GJ/y)	Net Energy Cost ($/GJ/30y)
10	V8056.v2	1966	Kamloops, BC	3,756	continuous	0.46	0.37	Yes		Exterior	6.81	1,616	42.89	8.12
					iaq_optHRV	0.32	0.26	Yes				1,414	35.37	7.17
					iaq_opt	0.32	0.26					1,512	39.87	7.10
					OTCavg	0.31	0.26		11.0			1,503	39.31	6.98
					OTCmin	0.31	0.26		11.0			1,503	39.31	6.98
739	BC10	1989	Vancouver, BC	3,007	continuous	0.32	0.31	Yes		Exterior	2.86	3,649	48.27	7.17
					iaq_optHRV	0.24	0.23	Yes				3,376	43.23	6.77
					iaq_opt	0.24	0.23					3,768	51.45	6.52
					OTCavg	0.25	0.17		16.0			3,737	50.79	6.39
					OTCmin	0.33	0.22		19.0			4,004	56.04	6.89
383	L4367.v2	1965	Toronto, ON	4,082	continuous	0.37	0.30	Yes		Exterior	4.66	4,576	42.30	8.86
					iaq_optHRV	0.26	0.23	Yes				4,066	34.01	7.98
					iaq_opt	0.26	0.23					4,452	42.45	7.92
					OTCavg	0.26	0.21		18.0			4,383	41.02	7.73
					OTCmin	0.32	0.23		22.0			4,577	44.60	8.10
683	RCD05	1989	Toronto, ON	4,082	continuous	0.34	0.30	Yes		Exterior	2.66	5,949	66.44	9.57
					iaq_optHRV	0.25	0.24	Yes				5,301	55.58	8.15
					iaq_opt	0.25	0.24					6,005	71.28	8.86
					OTCavg	0.26	0.16		22.0			5,852	68.12	8.39
					OTCmin	0.34	0.24		28.0			6,406	78.60	9.98
568	A1045.v2	1962	Saint John's, NF	4,804	continuous	0.45	0.37	Yes		Interior	4.68	3,946	40.32	4.44
					iaq_optHRV	0.32	0.27	Yes				3,368	32.70	4.27
					iaq_opt	0.32	0.27					3,913	40.21	4.06
					OTCavg	0.32	0.24		15.0			3,822	38.98	4.00
					OTCmin	0.36	0.27		18.0			3,963	40.88	4.05
683	S6076.v2	1946	Regina, SA	5,920	continuous	0.39	0.31	Yes		Exterior	5.19	7,894	40.22	5.26
					iaq_optHRV	0.28	0.23	Yes				7,463	34.79	5.00
					iaq_opt	0.28	0.23					7,645	39.12	4.52
					OTCavg	0.29	0.23		22.0			7,635	38.77	4.45
					OTCmin	0.29	0.23		22.0			7,635	38.77	4.45
765	WPG19	1989	Winnipeg, MA	5,889	continuous	0.32	0.30	Yes		Exterior	1.36	3,890	60.60	4.68
					iaq_optHRV	0.27	0.26	Yes				3,578	54.39	4.56
					iaq_opt	0.27	0.26					4,419	71.44	4.60
					OTCavg	0.29	0.19		42.0			4,435	71.74	4.57
					OTCmin	0.32	0.26		46.0			4,643	75.93	4.71

iaq_opt = approximately constant monthly total air change rate (iaq_optHRV is identical but includes heat recovery)

OTCavg = Outside temperature control, matching (or slightly higher) average Oct-Apr total air change rate (column avg. ACH) to iaq_opt run

OTCmin = Outside temperature control, matching monthly minimum Oct-Apr total air change rate (column min. ACH) to iaq_opt run

Appendix F Retrofit Rules

The factors and tables in the Rule.xls sheet determine the upgrade path for each house in the database. Other rule sheets could be generated to determine alternate retrofit paths.

In addition to the rules, certain factors were left as variables to allow for different scenarios. These variables include:

- retrofit level (LOW, MID, HIGH),
- whether to retain interior or exterior finishes (if not retained, the rules would determine whether or not to retrofit, based on other criteria),
- maximum added wall RSI (typically 3.0) - a factor in urban environments with limited side-yard space,
- whether or not to upgrade mechanical systems,
- ventilation factors -
  - whether to allow HRVs (to allow comparisons with and without HRV),
  - ventilation control (continuous, IAQ optimal and OTC),
  - whether to continue operation during the summer (May - September)
- Economic criteria to cancel retrofit on a specific house (based on LCEC, $/GJ)

Once these variables had been specified, a run could commence by loading the first house in the database. Based on retrofit level, region (and NECH zone within the region), and space heating fuel type, the program would look up goal RSI values for walls, basements, heated crawlspaces, ceilings and overhanging floors (and ER values for windows).

The program would then match a retrofit section from the database of building sections that would, if possible, meet the goal requirements. In some cases, other rules specified limitations on available choices, for example:

- if the city location matched a list of high density urban centres, then the program would invoke the maximum added wall RSI input, and if exceeded, would force an interior retrofit, or if that were not allowed would limit the exterior retrofit to the maximum,
- pre-1945 houses in Ontario were assumed to be masonry finish and the program used interior retrofits only.

Only whole-house retrofits were considered, primarily because of the limited amount of information on the air-tightening effects of retrofits - most of which was concerned with whole-house retrofits.

Air-tightness data was used if it existed for the base house, otherwise an NLA value was looked up, based on the region and age of house. The degree of air-tightening accomplished with the retrofit was linked to new house air-tightness in the region (construction industry capabilities), and the level of retrofit - specifically the selected wall retrofit (other portions of the house were assumed to be retrofitted to a similar degree).

Space and water heating systems were retrofitted according to a schedule based on level of retrofit and energy source (for example, electric and wood heating were not changed, while gas and oil systems were upgraded to mid-efficiency at the LOW and MID levels, and to integrated condensing systems at the HIGH level of retrofit). Note that heat pumps were not specified as an upgrade for electric systems - primarily because of limitations in the simulation model.

Ventilation systems were sized on the basis of a comparison with a specified ventilation requirement (selected as 0.30 ac/h) and April/October total ventilation (forced plus natural). In addition, ventilation on-time was calculated for each month for IAQ optimal and OTC systems.

The utilities base load was reduced according to a schedule, based on the level of retrofit (no change for LOW, 10% reduction for MID, and 20% reduction for HIGH). The base load was not reduced, however, in houses with combustion space heating systems if they were in regions dominated by hydro-electric generation, as reducing electrical utilities consumption in these house would increase carbon dioxide generation due to space heating.