OVERHEATING AS A

FACTOR IN

HOUSE DESIGN

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The project also led to additional material which is incorporated in a new book published by Canada Mortgage and Housing Corporation. The book, entitled "TAP THE SUN - PASSIVE SOLAR TECHNIQUES AND HOME DESIGNS", includes an Excel spreadsheet program, called "House Comfort Design Checker" as well as documentation for better passive solar home design. A copy can be obtained by calling Canada Mortgage and Housing Corporation at (613) 748-2367.

ABSTRACT:

Traditionally, houses have been designed without the application of any analytical tools with which to determine the applications of the design on thermal comfort. The emerging need for energy conservation and the deliberate attempts to better use solar energy have placed new emphasis on predicting the comfort conditions of houses.

A survey was carried out of occupants living in monitored, energy efficient and passive solar houses. Correlations of the survey and monitored results showed that discomfort was experienced by the occupants if the inside temperature exceeded set-point temperatures by 4C for more than 4% of the hours in a month.

This result was used in a series of hourly simulations carried out for houses in Vancouver, Edmonton, Toronto, Montreal and Halifax. A range of mass levels, conservation levels and internal gains were used to determine guidelines for recommended south glazed area to maintain acceptable levels of comfort. October was found to be the critical month for overheating in all the locations. Guidelines for overhang shading were also developed.

Various simulation software packages were evaluated from the point of view of their usefulness in the design process. Design guidelines and a spreadsheet comfort design checker were produced.

ABRÉGÉ

Traditionnellement, la conception des habitations se faisait sans l'utilisation d'outils analytiques permettant d'en déterminer les incidences sur le confort thermique. La nécessité de conserver l'énergie et les tentatives en vue d'une meilleure utilisation de l'énergie solaire font en sorte qu'il devient de plus en plus nécessaire de prévoir les conditions de confort des habitations.

Un sondage a été effectué auprès des occupants d'habitations à haut rendement énergétique et à chauffage solaire passif sélectionnées pour monitorage. Les corrélations entre les résultats du sondage et les lectures prises ont montré que les occupants éprouvaient de l'inconfort lorsque les températures intérieures dépassaient la température de consigne de 4 °C pendant plus de 4 p. 100 du temps au cours d'un mois donné.

Ces résultats ont été utilisés dans une série de simulations horaires effectuées dans des habitations situées dans les villes de Vancouver, Edmonton, Toronto, Montréal et Halifax. Différents niveaux de masse, de conservation d'énergie et d'apport interne ont été utilisés pour déterminer les lignes directrices à recommander en matière de maintien de niveaux acceptables de confort, relativement aux vitrages exposés au sud. Le mois d'octobre s'est révélé être le mois critique à tous les emplacements, du point de vue du surchauffement. Des lignes directrices sur des dispositifs d'ombrage en saillie ont donc également été mises au point.

Enfin, différents progiciels de simulation ont été évalués du point de vue de leur utilité au cours du processus de conception. Des lignes directrices et un logiciel d'évaluation du confort ont par la suite été produits.

EXECUTIVE SUMMARY

Residential housing is usually designed without the use of analytical tools for determining thermal confort. In an era of increasing energy conservation, along with increasing areas of high efficiency glazings, solar overheating is a potential problem that must be addressed by residential designers.

The purpose of this study was to develop simple tools for use by designers at the conceptual stage of design and to evaluate and suggest improvements to existing residential simulation software for use in the more detailed stages of design. The study focussed onsolar overheating during the heating season - establishing survey-based criteria for determining, and simulation tools for predicting, passive solar overheating.

A survey of occupants of monitored houses established that they considered overheating to be excessive if temperatures exceeded normal or thermostat set-point values by 4C for more than 4% of the hours in a period of a month or more.

Existing simulation software was surveyed for suitability, in predicting solar overheating, for use by residential building designers. HOT-2000 could be used by designers at the sketch and detailed design stages, with appropriate changes to its inputs and outputs, and incorporating a modified version of the overheating algorithms incorporated in a previous version. Enerpass or Suncode hourly simulation programs, with modifications to their inputs and outputs, could be used at the detailed design stage. Both Enerpass and Suncode achieved a reasonable overheating prediction match with results from monitored houses.

Detailed hourly simulations were performed for houses in five cities across Canada, in order to develop design guidelines to be incorporated into the *"Passive Solar Techniques for Canadian Housing"*, and into a spreadsheet-based program - *"House Comfort Design Checker"*. The simulations covered:

- a range of conservation levels (conventional, R-2000 and Advanced),
- a range of internal gains due to utilities (12.9 kWh/day to 26.0 kWh/day),
- a range of levels of thermal storage (light wood frame/gyproc to the use of brick and concrete feature walls, concrete floor topcoats, etc.),
- a range of south window overhangs, and
- various envelope configuration changes (windows, wall types, etc.).

The simulations covered a range from 44 to 54 degrees latitude - a range including most of the major cities in Canada. October was found to be the critical heating season month for solar overheating. Changing to more efficient glazing types resulted in slightly less overheating (the increased glazing thermal efficiency has a secondary effect on reducing building total heat loss, but a primary effect on reducing solar heat gains).

Guidelines were developed for designing overhang shading to maximize winter solar gains while controlling overheating in the summer and fall.

Guidelines to prevent excessive overheating were developed that limit south glazed area - see Summary Table.

SUMMARY TABLE - Maximum South Glazed Area to Avoid Excessive Overheating[1] (0.6m overhangs located 0.3m above glazings)

		Internal Heat Gains		
		26.0 kWh/day	17.4 kWh/day	12.9 kWh/day
	Mass Level	Maximum South Glazed Area to avoid Excessive Overheating (% of heated floor area)		
Conventional	Low	5.1%	5.7%	6.5%
	Medium	6.3%	6.5%	8.2%
	High	8.1%	9.1%	10.1%
R-2000	Low	3.1%	3.9%	4.3%
	Medium	3.6%	4.9%	5.3%
	High	5.0%	6.5%	6.8%
Advanced	Low	NR[1]	2.8%	3.5%
	Medium	NR	3.6%	4.6%
	High	NR	5.0%	5.9%

[1] NR: high levels of internal gains are not recommended in houses with highly energy efficient envelopes.

[1] Excessive Overheating defined as more than 4% of the hours in the critical overheating month (October) greater than 25C (the thermostat set-point plus 4C).

RÉSUMÉ

Les habitations sont habituellement conçues sans l'aide d'outils analytiques permettant d'en déterminer le confort thermique. À notre époque de conservation énergétique croissante et d'utilisation accrue de vitrages à haut rendement, le surchauffement solaire est un problème possible auquel les concepteurs d'habitation doivent trouver une solution.

La présente étude a été entreprise dans le but de mettre au point des outils simples à l'intention des concepteurs à l'étape de l'étude technique, ainsi que pour évaluer les logiciels existants de simulation utilisés aux étapes plus avancées de la conception et suggérer les améliorations à apporter à ces derniers. L'étude portait principalement sur le surchauffement solaire au cours de la saison froide - et visait à établir des critères fondés sur des sondages, en matière de surchauffement solaire passif, de même que des outils de simulation pour prévoir l'occurrence du problème.

Un sondage réalisé auprès des occupants de maisons soumises à un monitorage a permis d'établir que ces derniers considéraient que le surchauffement était excessif lorsque les températures dépassaient les valeurs normales ou de consigne de 4 °C pendant plus de 4 p. 100 du temps au cours d'une période d'un mois ou plus.

Nous avons également étudié les logiciels de simulation existants pour déterminer leur capacité à prévoir le surchauffement solaire, en vue de leur utilisation par les concepteurs d'habitations. HOT-2000 pourrait être utilisé par ces derniers aux étapes de l'élaboration des plans et de la conception détaillée moyennant des modifications appropriées des données d'entrée et de sortie et l'incorporation d'une version modifiée des algorithmes de surchauffement utilisés dans une version antérieure. Les logiciels de simulation horaire Enerpass ou Suncode pourraient quant à eux être utilisés à l'étape de la conception détaillée moyennant des modifications des données d'entrée et de sortie. Tant Enerpass que Suncode ont procuré une correspondance raisonnable entre les prévisions et les mesures prises.

Des simulations horaires détaillées ont été effectuées dans des habitations réparties dans cinq villes canadiennes, en vue de l'élaboration de lignes directrices à incorporer au guide sur les techniques solaires passives pour les habitations canadiennes et à un logiciel de type chiffrier servant à l'évaluation du niveau de confort. Les simulations ont porté sur les points suivants :

- niveaux de conservation énergétique (classique, R-2000 et avancée),
- niveaux d'apport interne des services publics (de 12,9 kWh/jour à 26,0 kWh/jour),
- niveaux de stockage thermique (ossature légère en bois et plaques de plâtre, murs de brique, murs de béton, revêtements de plancher en béton, etc.),
- divers dispositifs d'ombrage des fenêtres exposées au sud et
- diverses modifications de l'enveloppe (fenêtres, types de mur et autres).

Les simulations ont porté sur des habitations situées à des latitudes allant de 44 degrés à 54 degrés - où sont situées la majorité des principales villes canadiennes. Le mois d'octobre s'est révélé être le mois critique du point de vue du surchauffement solaire. L'utilisation de types de vitrages plus efficaces a conduit à un surchauffement légèrement moindre (l'efficacité thermique accrue des vitrages a une incidence faible sur la déperdition de chaleur totale du bâtiment, mais une incidence élevée sur la réduction des apports par rayonnement solaire).

Des lignes directrices ont en conséquence été mises au point en vue de la conception de dispositifs d'ombrage qui permettraient de maximiser les apports par rayonnement solaire en hiver tout en réduisant le surchauffement en été et à l'automne.

Des lignes directrices visant à prévenir le surchauffement excessif ont également été mises au point en ce qui a trait à la surface maximale des vitrages exposés au sud. Voir à cet effet le tableau récapitulatif ci-dessous.

TABLEAU RÉCAPITULATIF - Surface maximale des vitrages exposés au sud pour éviter un surchauffement excessif[1] (saillies de 0,6 m à 0,3 m au-dessus des vitrages)

Masse		Apports thermiques internes 26,0 kWh/jour	17,4 kWh/jour	12,9 kWh/jour
		Surface maximale des vitrages exposés au sud pour éviter un surchauffement excessif (en % de la surface chauffée des planchers)		
Classique	Faible	5,1 %	5,7 %	6,5 %
	Moyenne	6,3 %	6,5 %	8,2 %
	Élevée	8,1 %	9,1 %	10,1 %
R-2000	Faible	3,1 %	3,9 %	4,3 %
	Moyenne	3,6 %	4,9 %	5,3 %
	Élevée	5,0 %	6,5 %	6,8 %
Avancée	Faible	NR[1]	2,8 %	3,5 %
	Moyenne	NR	3,6 %	4,6 %
	Élevée	NR	5,0 %	5,9 %

1 NR; des niveaux élevés d'apports internes ne sont pas recommandés dans les habitations dont l'enveloppe présente une résistance thermique élevée.

Le surchauffement excessif étant défini comme une température supérieure à 25°C (la température de consigne du thermostat plus 4°C) pendant plus de 4 p. 100 du temps au cours du mois critique (octobre).

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Le surchauffement excessif étant défini comme une température supérieure à 25°C (la température de consigne du thermostat plus 4°C) pendant plus de 4 p. 100 du temps au cours du mois critique (octobre).

1 INTRODUCTION

1.1 Background

Traditionally, houses were designed without the application of any analytical tools with which to determine the implications of the design on thermal comfort. However, new Canadian housing has changed significantly over the past decade. Surveys made in 1983 and 1989 indicate that houses became 30% more air-tight over that period. Since the 1989 survey, air barrier requirements in the 1990 National Building Code were increased. Thermal insulation levels, heating system efficiencies, ventilation and combustion venting strategies have also been improved. Many of the features of R-2000 houses are being incorporated into current conventional houses. The introduction of the National Energy Code for Houses and the revised National Building Code will reinforce this trend through air-tightness standards.

This emergence of energy conservation and deliberate or accidental use of passive solar energy have placed new emphasis on predicting the comfort conditions of a house. Computer thermal analysis models in current use are primarily designed to assess energy flows and often completely bypass the issue of discomfort due to overheating or, with more detailed programs, their complexity makes them difficult for designers to use.

Recent advances in window design, resulting in quantum improvements in their thermal performance, are expected to effect a more liberal use of windows, as they are generally perceived as assets to the quality of indoor spaces. Increased use of energy conserving features, in combination with larger areas of south-facing windows, will create "passive solar houses" - perhaps unintentionally, and without the designer having taken steps to ensure the comfort of the occupants.

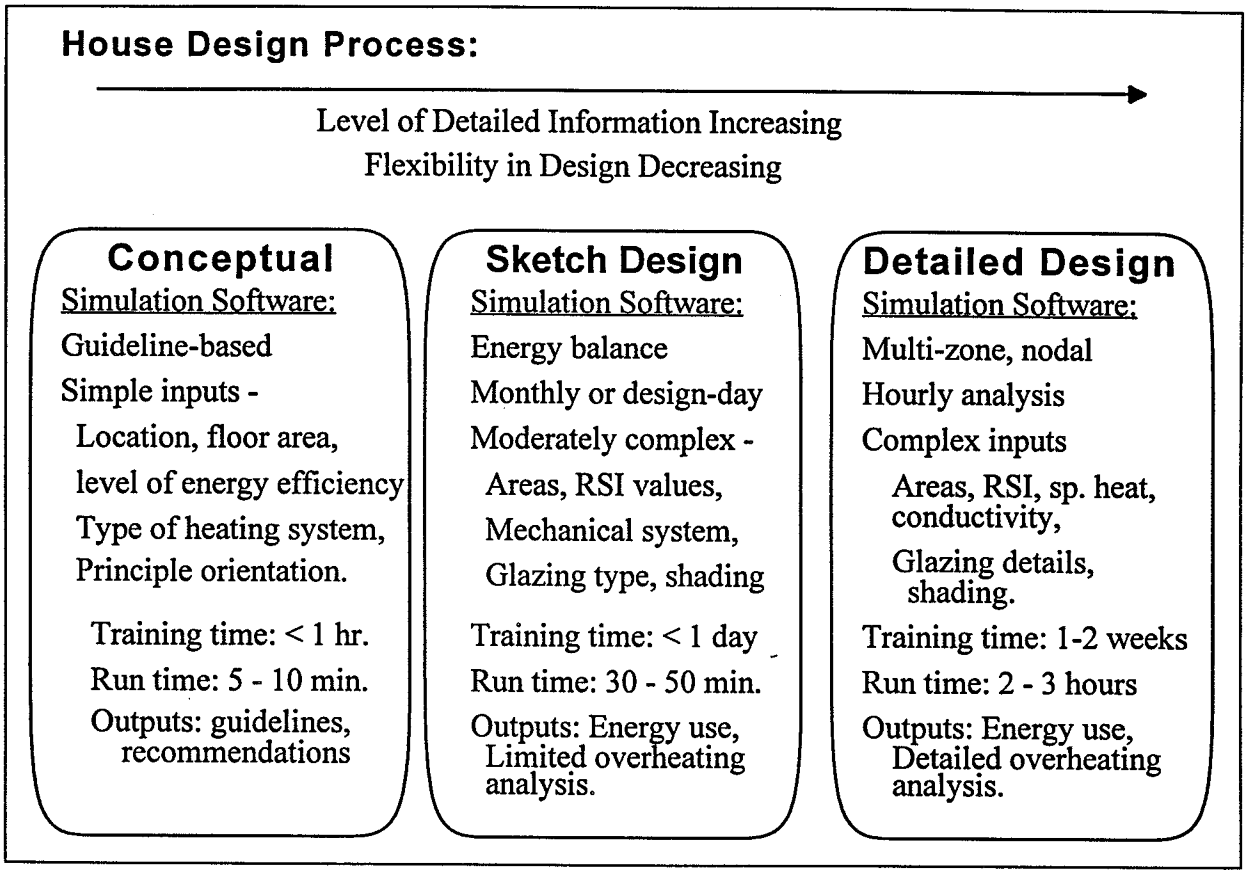
Exacerbating this situation is the increase in internal heat gains due to an ever-increasing use of electrical equipment in the modern home - including computers, multiple television sets, home theatre and a variety of small appliances. Continuously operating fans to circulate air within the house, to provide improved air quality and to equalize temperatures, are also a source of additional heat that must be accounted for in determining overheating.

1.2 Issues

Residential overheating has not been well understood or modelled. From the perspective of optimizing the use of solar radiation for space heating, overheating is a critical phenomenon because it determines the upper limit of solar utilization. Its present imprecise understanding has led to passive solar house designs that either under-perform by a significant margin or create discomfort conditions. Also, modelling energy use without accounting for occupant comfort will result in houses that use more energy than predicted - when the occupants open windows to reduce overheating on clear days. This mismatch between intended results and actual performance, combined with the anticipated increase in the use of windows, suggest that tools need to be developed that will enable house designers to precisely understand and model overheating so as to fully exploit the solar potential.

These modelling tools must be tailored to the stage in the design process (Fig. 1.1)

Figure 1.1 Design Process - Modelling Requirements



1.3 Objectives

The objectives of this project were to develop simple tools, and to provide the basis for the development of more sophisticated tools for house designers, to enable them to fully utilize solar energy for space heating, through a better understanding of overheating during the heating season. To facilitate these objectives, a further ojective was to determine the conditions occupants find constitutes overheating.

2 RESULTS

2.1 Methodology

The project involved the following activities to carry out the objectives of the project:

1. Consult with Expert Panel on Passive Solar Design
2. Search for candidate houses,
3. Identify the conditions of overheating,
4. Select computer thermal analysis software for detailed review,
5. Evaluate computer programs in modelling overheating,
6. Develop better correlations for modelling overheating,
7. Develop practical rules for commonly used house types and designs, and
8. Recommend modifications to preferred computer software.

Consultation with Expert Panel on Passive Solar Design

Two consultative groups were created: one in the Toronto area, and one in the Vancouver area. This consultative process involved groups of 4-6 persons in each panel, made up of architects, designers, home builders and simulation specialists.

The Toronto group was composed primarily of experienced passive solar design professionals. Subsequent follow-up comments were solicited by correspondence or telephone/facsimile.

EXPERT PANEL MEETING NOTES:

The following summarizes the results of the Toronto meeting with the expert panel. Some findings include:

- Overheating often caused by -
  - sloped glass,
  - locating excessive glass area in upper portion of house,
  - carpet covering thermal storage mass (concrete floor)
- Summer is not considered to be a problem as solar gains are not needed and **can** be excluded with overhangs or deciduous vegetation,
- Assume that high performance windows require reduced glass areas to prevent overheating due to higher thermal resistance.

The second, Vancouver area group was consulted in person later in the project, to evaluate the "*Passive Solar Techniques for Canadian Housing*" and the spreadsheet "*House Comfort Design Checker*". This group was composed primarily of designers with less experience in designing passive solar houses (see section 2.7).

2.2 Search for Candidate Houses

In order to determine conditions that occupants found constituted overheating, a survey of 47 monitored houses across Canada was carried out (see Appendix A).

Descriptive information on each house was obtained to allow preliminary screening. A database of these low energy houses was created and an analysis of the documentation and monitored summary data for these houses was used to select houses in each geographic region that had a potential for overheating, based on:

- envelope characteristics,
- type of passive solar system
- region,
- orientation,
- climate,
- type of heating system, and
- appliance use.

This database was reduced to a short list of only seven houses, based on the following factors:

- availability of hourly data,
- availability of plans,
- suitability of house -
  - sufficient south glazed area to possibly result in solar overheating,
  - no significant wood heating (which might cause unexplained overheating)

In addition to incomplete/lost data, there is a significant problem with the accessibility of hourly data due to incompatible computer files. In many cases, the hourly files exist only in formats and/or media accessible to computers that either no longer exist or are very difficult to access (Aeolian Kintetics tapes, HP85 tapes, CR21 tapes, for example).

The seven houses selected for detailed analysis were:

- Yarrow Passive Solar House (Yarrow, B.C.)
- North Vancouver Passive Solar House (North Vancouver, B.C.)
- CMHC Healthy house (Vancouver, B.C.),
- Cold Climate house (Edmonton, Alberta),
- INNOVA Advanced house (Ottawa, Ontario),
- Novtec Advanced house (Montreal, Quebec), and

- Nova Scotia R-2000 house

2.3 Identify the conditions of overheating

The main focus of this study is overheating due to solar gains during the heating season (somewhat arbitrarily defined as October to April). In defining overheating, two primary variables exist -

- discomfort temperature threshold, and
- percentage of hours that exceed that threshold.

These are not independant variables, so one of them must be fixed in order to facilitate the analysis. An overheating threshold of 4C above the house average heating season temperature (not including unoccupied basement) was used[2].

An occupant questionnaire was completed and administered to the occupants of six houses (occupants of Novtec house unavailable):

- North Vancouver passive solar house in North Vancouver, B.C.,
- Yarrow passive solar house near Chilliwack, B.C.,
- CMHC Healthy house in Vancouver
- Cold Climate R-2000 house in Edmonton, and
- INNOVA Advanced house in Ottawa (air conditioned), and
- Nova Scotia R-2000 house in Halifax.

Comparing occupant comfort response to measured temperatures shows the following:

- The passive solar house in North Vancouver uses a combination of direct gain and sunspace. The single occupant has lived in the house for 13 years and was resident at the time of monitoring in 1984/1985. The occupant sets the thermostat at 21C with a night setback (average heating season temperature of 20.0C). The occupant also always keeps a bedroom window open. The occupant reports no heating season overheating in the house (during the monitored period, the house average temperature exceeded 24C by 4% or less of the hours in every month - App. B.1), although the occupant reports that the solarium overheats in the fall (25C maximum in October - less than 24C maximum in other winter months).

[2] Based on the ASHRAE thermal sensation scale, which when evaluated for comfortable conditions, results in an acceptable band of 4C above and below the desired temperature. Conditions outside that band were deemed to be uncomfortable by 90% of a large group of similarly clothed adults.

- The Yarrow house has over 9% of the floor area in south windows, but most of the solar-coupled floor is covered with tile on 38mm of concrete on a wood subfloor. The single occupant of the house prefers a cool environment - setting the thermostat at 20C with a night setback to 15C[3] (average monitored heating season temperature of 19.9C). She occasionally opens the kitchen window in the fall when it is too warm (at the time of monitoring, 6% of the October hours exceeded 23.9C - App. B.1). The present occupant does not experience mid-winter overheating (at the time of monitoring, less than 4% of January-February hours exceeded 23.9C). The occupant reports some upstairs overheating in the summer, particularly on the west side.
- The occupants of the Vancouver Healthy House preferred a warm environment - they set the Living room thermostat at about 22C (average heating season temperature 21.9C)[4]. The occupants found the loft area above the living room to be too warm during the winter around mid-day (note that the loft temperature was not monitored, but based on results from the Yarrow house, a clear day stratification of about 2C is likely), and generally stuffy with a lack of air circulation. All the loft windows are triangular and cannot be opened. The south-side living room rarely exceeded 25.9C (maximum 4 hours in February) and they reported it to be comfortable. The living room exceeded 23.9C (loft exceeded 25.9C if stratification of 2C) for an average of 9% of the time during the October to April heating season (App. B.1).
- The occupants of the Edmonton house prefer a cooler environment - with an average heating season temperature of 20.2C. They found the house overheats on the main floor during sunny spring and fall days. They also used blinds to reduce discomfort due to glare, even when the house was not too hot. The south-side family room in the Edmonton house exceeded 24.2C for at least 5 hours in every winter month - but for 35 hours in February (5% of the time) and 2% to 3% of the time in April and March (App. B.1).
- The occupants of the Ottawa Advanced house preferred slightly warmer temperatures (average heating season temperature of 20.7C) and experienced no overheating during the heating season. The Family room on the south side of the house did not exceed 24.7C during the heating season (also, the air conditioning did not come on during this period) - App. B.1. All south windows had overhangs.

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[3] New occupant - original occupants used day/night set-points of 21C/18C.

[4] Note that the downstairs bedroom temperature was not included in the 'comfort average' since they reported that they found the bedroom too cold.

- Occupants of the Novtec house left with no forwarding address, so a questionnaire could not be administered. The house exceeded a threshold of 24.4C for 4% to 5% of the spring and fall hours. Also, the air conditioning operated 1% to 4% of heating season hours (App. B.1).
- The occupants of the air conditioned (set to 25C) Nova Scotia house also experienced virtually no overheating (also, the occupants had a preference for higher than normal temperatures of 21C to 23C). Windows were opened occasionally during cooking. No information on air conditioning on-time was available.

Table 2.1 Summary of Occupant Reported Overheating and Monitored Results

	Discomfort threshold temperature (C)[1]	Occupants report overheating?	Temp. exceeded threshold (% of hours)	Period (during heating season)
N. Van. house	24.0	no	0% to 4%	all months
Yarrow house	23.9	yes: fall	6.0%	October
Van. Healthy - loft	25.9	yes	avg ~9%	all months
- living room	25.9	no	0% to 1%	all months
Ottawa	24.7	no	0.0%	all months
Nova Scotia	26.2	no	0.0%	all months
Edmonton	24.2	yes: spring & fall	2% to 5%	spring
Novtec Advanced	24.4	N/A	4% to 5%	spring and fall
Average	24.8			

[1] 4C above average heating season or set-point temperature

From the table we can see that occupants reported overheating in houses with over 4% of the hours[5] in a period exceeding the discomfort threshold temperature (Yarrow, Edmonton and Vancouver Healthy houses). Occupants in houses with 4% of the hours, or less, exceeding the threshold temperature reported no overheating (North Vancouver, Ottawa, Nova Scotia).

2.4 Select Computer Thermal Analysis Software for Detailed Review

The goal of this task was to select one or more computer programs for use by residential designers to determine overheating[6].

A variety of computer thermal analysis programs were evaluated with respect to their:

- ease of use by a building designer,

[5] 4% of the time is about 30 hours of overheating in a one month period. In the spring or fall, this amounts to 2 to 3 hours per sunny day.

[6] A secondary goal was to review available hourly simulation software for the performance of a parametric analysis to develop design guidelines as part of this study.

- their ability to present their results in a manner that is useful to a building designer, and
- ability to predict residential overheating accurately.

An effort was made to select programs of varying levels of sophistication - suitable for different stages in the design process. Programs investigated:

HOT-2000 (Canada):

Interface (input and output) -

- "user hostile" interface[7],
- detailed numeric input and output (two screen, simplified input version to be available summer, 1996; Windows "port" of existing program by end 1996),
- less than $400 cost,
- developmental support through NRCan.

Technical Capabilities (including overheating, energy prediction, etc.) -

- single zone monthly simulation (a second basement 'zone' has limited assignable characteristics to define it),
- intended for residential space heating and cooling evaluations,
- extensive Canadian weather files available (easily customisable),
- cannot presently model sunspaces,
- very limited modelling of architectural shading devices (overhangs only),
- uses 31 temperature 'bins' in each month, enabling minimal evaluation of overheating (via calculation of cooling requirement - note that one of the batch versions of HOT-2000 **contained a summer overheating calculation**, but it was dropped due the excessive calculation time it took on the computers available at the time),
- no real correlation of insolation and temperature, however,
- limited modelling of mechanical systems,

In Summary -

- moderately complex inputs, however simplified input version should alleviate this problem by later this year,
- needs expanded overheating modelling capabilities.

REM Design (USA)

Interface (input and output) -

- reasonably user friendly inputs,

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[7] reviewed in *"Special Report: Energy Simulation Software for Home Builders and Designers"*, in Energy Design Update. April, 1996

- simplified input available (detailed numeric input available),
- less than $600 cost,

Technical Capabilities (including overheating, energy prediction, etc.) -

- single zone monthly simulation,
- intended for residential space heating and cooling evaluations,
- proprietary algorithms - technical details not available (generally based on ASHRAE methods, however).

In Summary -

- simplified input available,
- minimal overheating capability

Enerpass (Canada) -

Interface (input and output) -

- not very user friendly (a great deal of 'technical' input required),
- numeric input and output (including zone temperatures: minimum, average, maximum and hours within 2 C bands from less than 16 C to greater than 32 C),
- less than $500 cost,

Technical Capabilities (including overheating, energy prediction, etc.) -

- multiple node, multiple zone hourly simulation - so overheating calculation is possible,
- intended for residential and small to medium-sized commercial buildings,
- can model most sunspace configurations (although not as a default configuration),
- no modelling of architectural shading features,
- limited Canadian weather files,
- simplistic below grade calculation,
- moderately extensive modelling of mechanical equipment,
- developmental support by Enermodal (in-house program).

In Summary -

- quite complex inputs, however it is the only Canadian program capable of a detailed overheating analysis,
- input complexity could be reduced by creating a set of generic default files.

Suncode-PC (USA) -

Interface (input and output) -

- not very user friendly (a moderate amount of 'technical' input required),
- numeric input and output (extensive hourly outputs possible, but limited statistical analysis),
- less than $500 cost,

Technical Capabilities (including overheating, energy prediction, etc.) -

- multiple node, multiple zone hourly simulation - can predict overheating,
- intended for residential and small commercial buildings,
- PC version of SERI/RES (Solar Energy Research Institute - mainframe software),
- very limited Canadian weather files (purchased separately),
- limited modelling of architectural shading features (long overhangs and side fins),
- can readily model passive solar systems (including sunspaces, trombe walls, remote storage systems, etc.),
- simplistic below grade calculation,
- very limited modelling of equipment, although a number of passive solar systems are readily modellable (sunspaces, trombe walls, rock-bins)
- developmental support by Ecotope (in-house program).

In Summary -

- quite complex inputs, however it is the only program that models the full range of passive solar systems "out of the box",
- outputs need a statistical processor to make sense of large quantities of data.

DOE-2 (USA) -

Interface (input and output) -

- not user friendly (a great deal of 'technical' input required), although third party 'front-ends' available,
- extensive third party developmental support (a variety of main-frame and PC versions of the program exist, along with customised inputs and outputs - including graphic forms).
- different versions, but typically over $1,000 cost,

Technical Capabilities (including overheating, energy prediction, etc.) -

- multiple node, multiple zone, hourly simulation - can predict overheating,
- can be used for residential applications, but primarily intended for large commercial buildings,
- limited Canadian weather files (purchased separately),

- simplistic below grade calculation,
- extensive modelling of complex mechanical systems.

In Summary -

- too complex and expensive

The programs selected for detailed evaluation were:

- **HOT-2000**
  - widely used by builders and designers in Canada (also part of R-2000 certification),
  - in process of making interface more user-friendly,
  - capable (particularly in previous version) of modelling overheating,
  - Canadian development support (more readily influenced to make changes), and
  - validated against Canadian housing.
- **Enerpass**
  - capable of modelling overheating,
  - Canadian development support (more readily influenced to make changes), and
  - useful for detailed evaluations of comfort conditions
- **Suncode** (primarily for parametric analysis)
  - capable of modelling overheating, and
  - designed specifically for modelling passive solar residential buildings.

2.5 Evaluate Computer Programs in Modelling Overheating

There were two goals in this task:

1. Determine the strengths and weaknesses of each of the programs, in order to select the most suitable program(s) for use by designers, and
2. Select the program that models overheating most accurately[8].

Design Process Background and its Impact on Modelling Requirements:

As the design process moves from conceptual to more detailed, the level of detailed information increases, however the ability to easily change the design decreases (Figure 1.1). The type of modelling software that is suitable for each phase in the design process depends on:

- the amount and type of information that is available to describe the house,

[8] Note that this may or may not be one of the programs preferred for use by house designers, as accuracy is only one of the requirements in that selection.

- the amount of time the designer is willing to invest in the modelling process, and
- the amount and type of output information provided by the program.

In addition, the level of sophistication of the designer, with respect to passive solar design, will also determine the type of modelling used. For example, the designer of a building code-level house may only be willing to invest a small amount of training time and run-time in checking to see if the house will overheat - rules and guidelines would have to be sufficient. A designer of an R-2000 house is required to provide a HOT-2000 run (or its equivalent) as part of the house energy use compliance check, so this designer would likely use the first two levels of modelling (Figure 1). In addition, this type of designer is more interested in optimising the house for minimal energy use and is therefore more likely to be willing to spend more time on the modelling process[9]. Finally, the designer of a "passive solar house" - as distinct from a "conserver house" is a more likely candidate to use the final, most detailed modelling to ensure comfort in a house providing the highest levels of solar utilisation. Also, this type of designer may have sufficient experience to not need the guidelines provided at the conceptual stage. A modelling process needs to be created which can be entered or exited at any stage - depending on the needs and the level of sophistication of the designer.

2.5.1 Simulation Software Comparisons:

HOT-2000

- modified version 6 of HOT-2000 which models overheating was tried for several cases, however, at present it only models overheating in the summer. It would have to be further modified to model overheating for all months,
- reasonably good at predicting energy use; limited overheating analysis,
- normal program, version 7, models most residential mechanical systems,
- input interface needs to be made simpler and more user-friendly for use at the Sketch Design stage by a large audience of building professionals.
- models overhangs,
- modified version should be updated to incorporate current version 7 features,
- output has been added onto for many years and needs a complete overhaul.

In addition, we performed an evaluation of the **REM Design** program's user interface and found the differences between it and HOT-2000 to be relatively insignificant (more presets and defaults, but less flexibility), particular given that a more user-friendly Windows version of HOT-2000 is scheduled for delivery in the near future.

[9] At higher levels of modelling difficulty, the modelling may be carried out by specialists, rather than the house designer.

The hourly simulation programs (Enerpass and Suncode) currently require considerable "tuning" to achieve reasonable results. Also, some simplifications are built-in. For example, Enerpass assumes that all mass is exposed to the sun (unless a building component with multiple nodes is constructed). Each program has strengths and weaknesses -

Enerpass

- reasonably accurate at predicting temperatures and energy use,
- easy to perform multiple house runs for one location (batch),
- considerable flexibility in modelling mechanical systems (up to small or even medium sized buildings),
- needs a simpler, more user-friendly interface,
- crashes fairly often - sometimes due to user errors, but other times for no apparent reason,
- output is essentially a regurgitation of the input screens with little or no explanation. For example, building sections, windows, etc. are referred to by a two digit code in the output - requiring the user to look up descriptions in the Appendix of the manual. User input codes must be documented by the user as their characteristics are not output.
- sunspaces can be modelled, however air movement between spaces can only be scheduled on a time basis, not on the basis of temperature difference.
- does not model any type of shading device - a severe limitation for a program modelling passive solar buildings.

Suncode

- location(s) linked to each building file - multiple locations possible, but must edit building file to change location,
- inputs tend to be more "engineering" oriented (extinction coefficients for glass, for example),
- limited in its modelling of mechanical systems (no HRVs or heat pumps),
- appears to offer significant promise in its ability to model passive solar buildings:
  - models indirect gain (trombe walls), including modelling of thermocirculation,
  - models isolated gain (sunspaces),

  - models isolated storage (rock bins, hollow-core concrete slabs, etc.),
  - models phase change materials,
  - easy to set up multi-node storage in thick materials (brick walls or concrete floor slabs, for example),
  - allows for interzonal, temperature difference controlled movement of heat by fans,
  - allows "solar transfer" between zones to be scheduled (glass doors between sunspace and house, for example), and
  - allows "solar lost" (cavity reflection) and "solar-to-air" (solar absorbed by lightweight materials) to be specified.

- models overhangs and side-fins for shading,
- allows for input of skyline shading.
- has significantly more flexibility in terms of type and amount of output than does Enerpass (including the ability to graph user selected variables),
- uses what amounts to a line editor type of input interface, making it extremely unfriendly from a user's point of view. However, it uses more language descriptions than Enerpass, making it somewhat easier to understand (building sections are referenced by a user input name, while Enerpass uses only two digit numbers),
- uses three program modules - EDIT for constructing/modifying building files, LOADS for running the compiled building files, and VIEW for viewing/outputting the results. Each of these is run separately from the DOS prompt - a tedius process.
- needs a user friendly "front-end", along with a fairly extensive set of sample houses and a more readable and concise output.

Suncode was the primary program used for the parametric studies. These parametric simulations were used to develop the design "rules of thumb" which were incorporated into the *"Passive Solar Techniques for Canadian Housing"* designer's handbook, and into the associated spreadsheet-based program - *"House Comfort Design Checker"*, for use at the conceptual stage of design.

At the Sketch Design stage, a version of HOT-2000 could be used if it incorporated the overheating algorithms, and if its inputs and outputs were significantly simpler than at present.

With appropriate user-friendly "front-ends" either Enerpass or Suncode could be used in the final stages of design for detailed overheating analysis, although Suncode would be preferable as it allows for considerably more flexibility in passive solar buildings.

2.5.2 Determine Accuracy of Software in Simulating Overheating:

Detailed hourly monitored data was used for the selected houses, to determine winter comfort conditions. Weather records for simulations used Typical Meteorological Year (TMY) data.

Correlations were carried out for simulated hourly temperatures versus measured inside south-side (unless otherwise shown) temperatures (see Appendix B.1) with:
Suncode -

- Passive solar house in North Vancouver,
- Yarrow house, near Chilliwack, B.C.

Enerpass -

- CMHC Healthy house in Vancouver,
- Cold Climate house in Edmonton,
- Ottawa Advanced house, and
- Novtec house in Montreal.

The comparisons resulted in a number of findings:

- there was generally a reasonable match between simulated and measured with respect to average temperatures (Table 2.2), however there tended to be more variability (minimum to maximum range) in actual heating season temperatures than predicted,
- both programs were able to predict overheating (or not), based on the criteria developed from the occupant questionnaires - overheating occurs if more than 4% of the hours in a period (month or heating season) are greater than the discomfort threshold (average heating season temperature plus 4C).
- however, there is sufficient day-to-day variability in occupant lifestyle to ensure that simulations based on average profiles (thermostat set-point, utilities consumption, etc.) will not be able to achieve a reasonable match with actual hourly temperatures on a day-to-day basis,
- modelling simplifications, such as using one or two zones to represent the whole house, are difficult to compare to values measured in several locations throughout the house - the loft in the Vancouver Healthy house and the kitchen in the Novtec Advanced house, for example. More simulation zones are possible, however air and heat transfers between zones must then be known.

Table 2.2 Software Predictions of Overheating

	Average Oct-Apr measured temperature (C)	Average Oct-Apr predicted temperature (C)	Occupants report Overheating?	Simulation Predicts Overheating?
Using Suncode:				
N. Van. house	20.0	19.9	no	no
Yarrow house	19.9	19.6	yes (fall)	yes (fall)
Using Enerpass:				
Ottawa Advanced	20.7	21.5	no	no
Edmonton	20.2	20.7	yes (spring)	yes (spring)
Vancouver Healthy House	21.9	21.1	yes (loft) no (living room)	yes (loft) no (living room)
Novtec Advanced	20.4	20.6	N/A	no[1] (whole house)
Average	20.5	20.6		

[1] overheating in unoccupied Novtec house assumed if temperature exceeded measured average of 20.4 C plus 4C.

2.6 Parametric Simulations to Develop Overheating Correlations

In order to provide a basis for simulation and discussion, we developed a "model house" design of 141.8 square metres floor area on the main and second floors, plus a 74.0 square metre heated concrete basement. The intention was not to develop an ideal design, but one which was reasonably typical and that could incorporate the various passive solar features that we wanted to simulate and illustrate.

Some of these features included:

- incorporating south glazed areas and thermal storage into circulation areas to minimize heating occupants, while heating the building (2nd floor clerestory into upper hall/stairwell, for example),
- distributing solar gains as deeply into the space as possible to minimize glare effects and to maximize the use of thermal storage (locate windows near north-south exterior or interior walls to allow the light to spread out over the wall surface; and/or use interior, reflective light shelves, for example),
- glazing located high in the walls to distribute light and heat to the backs of the rooms and to reduce occupant overheating,
- developing basements[10] to make them brighter (more south glazing) to more fully utilize their thermal storage capabilities,

[10] Note that total heated floor area includes basement area in this report. If basements are unheated, the heated floor area does not include the basement area.

- sufficient thermal storage to reduce temperature swings to acceptable levels, for example -
  - double gyproc,
  - insulation on outside of concrete in basement (with increased south glazing in basement),
  - concrete topcoat on floors - effective with tiled floors, but relatively ineffective if carpeted,
  - concrete or brick "feature walls" - particularly in highly glazed areas where the sun impacts directly on the wall. Also, warm air can be blown through ducted hollow concrete block - thereby using the inside of the blocks for thermal storage - either in floors or walls,
- mechanical system designed to distribute air between floors - excess heat on one floor can be distributed to the "thin mass" (gyproc, etc.) on other floors - particularly the basement.

Simulations were performed using Suncode for a variety of conditions, with the goal being to approach the 4C above normal temperature threshold for 4% or fewer hours limit determined from occupant surveys (sec. 2.3). Simulations were carried out for:

- Five locations across Canada - Vancouver, Edmonton, Toronto, Montreal and Halifax,
- three levels of conservation, corresponding approximately to -
  - normal new construction,
  - R-2000 levels, and
  - Advanced house levels
- a range of south glazed areas (3% to 12% of heated floor area),
- a range of thermal storage mass -
  - light (normal gyproc over wood frame construction; concrete basement),
  - medium (same as light, except double gyproc on walls and ceilings), and
  - heavy (same as medium, plus concrete topcoat on main floor, internal solid concrete and ducted concrete block walls)
- a range of internal gains (the highest level slightly more than the current HOT-2000 default of 24 kWh/day, to allow for fans, but assuming some increase in appliance efficiency; the lowest level slightly higher than the approximately 11 kWh/day originally budgeted for the Advanced house program - again to all for fan energy use)-
  - 26.0 kWh/d (assumed typical for normal new construction),

  - 17.4 kWh/d (assumed typical for R-2000), and
  - 12.9 kWh/d (assumed typical for Advanced house construction)
- a range of overhang shading[11] (located 0.3m above all windows); widths of -
  - 0.6m,
  - 0.9m, and
  - 1.2m
- a range of glazing types -
  - double glazed, ER -23.2,
  - triple glazed or double glazed low E, ER -12.3, and
  - triple glazed, low E and argon filled, ER 2.7
- Air tightness factors were adjusted to result in total ventilation plus infiltration of about 0.27 to 0.30 air changes per hour in October - a level found to give reasonable indoor air quality for that critical month[12].
- Indoor temperature setpoints were assumed to be 21C (day), 18C (night) - although in the better insulated and/or high mass cases, the temperatures did not always drop to the night setpoint,
- Variations in non-south window area and distributions to determine effect of changes in design and orientation,
- Variations in total heat losses[13] to determine effect on recommended glazed area of building form and characteristics.

Base runs were carried out for all five locations. Assumptions included:

- light thermal storage (normal gyproc/wood frame construction),
- internal gains of 17.4 kWh/day (actually less than typical, but reflecting probable improvements in appliances and lighting),
- 0.6m overhangs on south windows (located 0.3m above glazings),
- glazing amounts - North, 3.0 m^2; East, 5.7 m^2; West, 0.9 m^2; South, varies (see Table 2.3).

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[11] Note that large roof overhangs can be achieved with the use of raised heel trusses - necessary to accommodate high levels of attic insulation.

[12] *"Indoor Air Quality Analysis for Detached Residences"*, by SAR engineering ltd for CMHC, March 1992: October was critical for IAQ since it is the month of the heating season with the lowest natural infiltration.

[13] Note that variations to R-2000 and Advanced houses are limited if the house is to meet program energy budgets. Also, conventional houses are increasingly governed by energy-related standards (NECH, for example).

Table 2.3 Summary of Base Run Results

Location		Glazing Type (ER)	S. Glazing (% floor area)	October 2nd floor (% of hours)	Overheating main floor (% of hrs)	basement (% of hrs)	Max. Temp. (C)	Heating Demand (GJ/year)
Vancouver	Normal	-23.2	6.0%	6.0%	6.0%	0.0%	27.8	55.4
	R-2000	-12.3	4.0%	6.0%	5.0%	0.0%	27.0	25.6
	Advanced	2.7	4.0%	9.0%	9.0%	0.0%	27.3	17.3
Edmonton	Normal	-12.3	5.0%	7.0%	7.0%	0.0%	27.6	87.9
	R-2000	-12.3	3.0%	6.0%	6.0%	0.0%	27.3	45.5
	Advanced	2.7	3.0%	7.0%	7.0%	0.0%	27.4	37.7
Toronto	Normal	-12.3	5.0%	6.0%	6.0%	0.0%	26.8	56.7
	R-2000	-12.3	3.0%	3.0%	2.0%	0.0%	26.2	34.8
	Advanced	2.7	3.0%	8.0%	9.0%	0.0%	27.4	24.0
Montreal	Normal	-12.3	5.0%	9.0%	9.0%	0.0%	28.7	74.0
	R-2000	-12.3	3.0%	8.0%	6.0%	0.0%	27.4	44.5
	Advanced	2.7	3.0%	14.0%	14.0%	1.0%	28.0	30.6
Halifax[1]	Normal	-12.3	5.0%	5.0%	4.0%	0.0%	27.4	63.6
	R-2000	-12.3	3.0%	1.0%	0.0%	0.0%	25.7	38.1
	Advanced	2.7	3.0%	4.0%	4.0%	0.0%	26.3	25.4

[1] Halifax hourly weather was unavailable for use with Suncode, so the TMY weather file for Bangor, ME was used (temperatures and insolation approximately mid-way between Halifax, NS and Fredericton, NB).

Maximum temperatures are similar in all the cases because other design parameters were adjusted in an attempt to achieve approximately 4% of overheating hours.

Note that it was not practical to perform simulations that would result in exactly 4% overheating for each run, so additional runs were performed to determine the change in hours of overheating as a function of change in south glazed area. This enabled us to adjust the glazed areas for the base and sensitivity simulations to achieve exactly 4% overheating. The effect on winter overheating of the East and West glazings used in the base houses was also determined, so that they could be removed from the final recommendations for recommended south glazing.

Simulations with different house orientations were performed in order to determine the effect of predominant east or west glazings. Although the effect of east or west glazings is significant with respect to summer overheating, the effect on **winter** overheating was quite small (about one quarter that for an equal area of south glazing).

A sample of hourly simulation results are included in Appendix B.2, including the following:

- base run TDR03L13[14] - this Toronto R-2000 house, with 3% of the total floor area (including heated basement) in south triple glazing (6.6 m^2), used a low level of thermal storage. Internal gains were 17.4 kWh/day. There were 0.6m overhangs located 0.3m above south glazings. Overheating[15] amounted to 3% and 2% of hours in October (main and second floor, no overheating in basement).[16] With a high level of thermal storage mass (TDR06H13) overheating amounted to 4% of hours in October (main and second floor, no overheating in basement) with 6% of the floor area in south windows (12.9 m^2). Space heating demand was reduced from 34.8 GJ/year (base case - Table 2.3), to 32.2 GJ/year with the high mass and larger south glazing area.
- run EDA05L08 - this Edmonton Advanced house, with 5% of the total floor area (10.7 m^2) in south 'super' glazing (ER ~ 2.7), with large 1.2m overhangs and a low level of thermal storage. Internal gains were 12.9 kWh/day. Overheating was excessive - amounting to 9% of October hours (second and main floors - no overheating in basement). Doubling the gypoc thickness (EDA05M08) reduced overheating to 3% and 4% of October hours (second and main floors respectively). Space heating demand was reduced slightly from 40.2 to 39.7 GJ/year. Further increasing the thermal storage to a high level and reducing the overhangs to 0.6m (EDA05H06) resulted in a slight increase in overheating - to 5% of October hours (second and main floors respectively). Space heating demand was further reduced to 37.3 GJ/year.

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[14] run ID: 1st letter refers to the city (Toronto, Vancouver, Edmonton, Montreal, Halifax),

2nd letter refers to type of solar system (Direct gain),

3rd letter refers to conservation level (Normal new construction, R-2000, Advanced),

next two numbers are the percentage of floor area in south glazing (05 to 12),

the sixth character refers to the thermal storage level (Low, Medium, High),

next number refers to the level of internal gains (0 - 12.9 kWh/d, 1 - 17.4 kWh/d, 2 - 26.0 kWh/d),

the last number refers to the glazing/overhang combination

0, 1, 2 double glazing (0.6m, 0.9m, 1.2m respectively)

3, 4, 5 triple glazing or double glazing with low E (0.6m, 0.9m, 1.2m respectively)

6, 7, 8 triple glazing with double low E, argon filled (0.6m, 0.9m, 1.2m respectively)

[15] Overheating defined as warmer than 25C (4C above day-time set-point temperature of 21C).

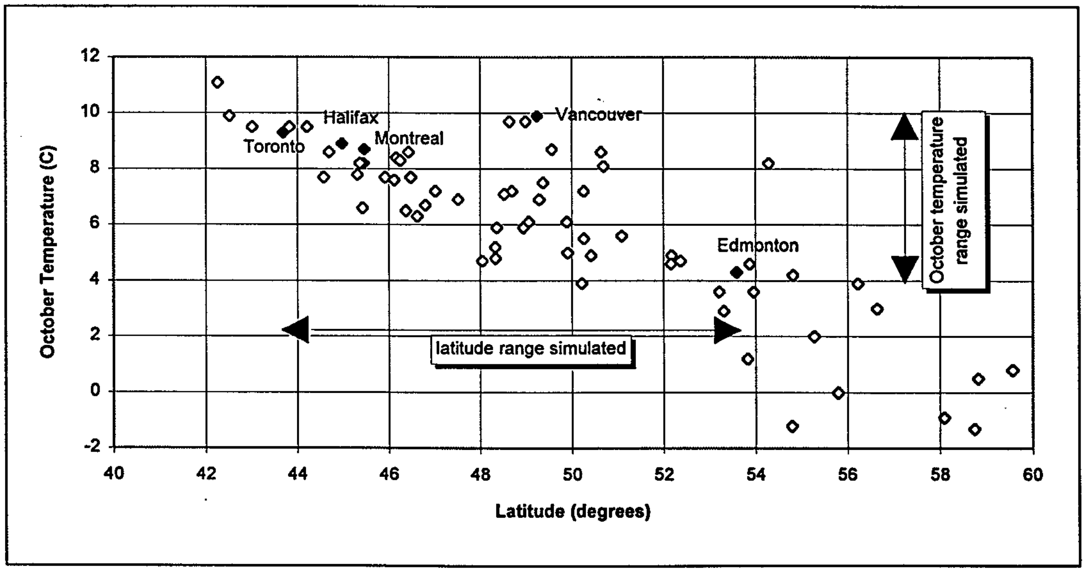
[16] a further run with envelope heat losses increased 10% (to test for sensitivity to envelope characteristics), resulted in a reduction of overheating hours of only 1.5%. Also, the house heating demand of 41 GJ/year did not meet the R-2000 space heating budget of 35 GJ/year.

- base run VDN06L10 - this Vancouver conventionally constructed house, with 6% of the total floor area in south double glazing (12.9 m^2), overheated 6% of October hours with normal light construction. Internal gains were 17.4 kWh/day. There were 0.6m overhangs located 0.3m above all south glazings. Replacing the double glazed windows with triple glazed (run VDN06L13) or double glazed with one low E coating **reduced overheating** slightly, to 5% of October hours (main and second floors respectively). Space heating demand for the base house of 55.4 GJ/year was also reduced to 51.0 GJ/year with the better glazings, thereby achieving the double benefit of reduced overheating and reduced energy use.

Analysis of these and approximately 70 other simulations, resulted in design rules for maximum recommended south glazed area, summarized in Table 2.5. These are incorporated into the *House Comfort Design Checker* and the Designer's Manual.

The critical days for overheating were found to be clear days in October, and to a lesser extent in March and April[17].

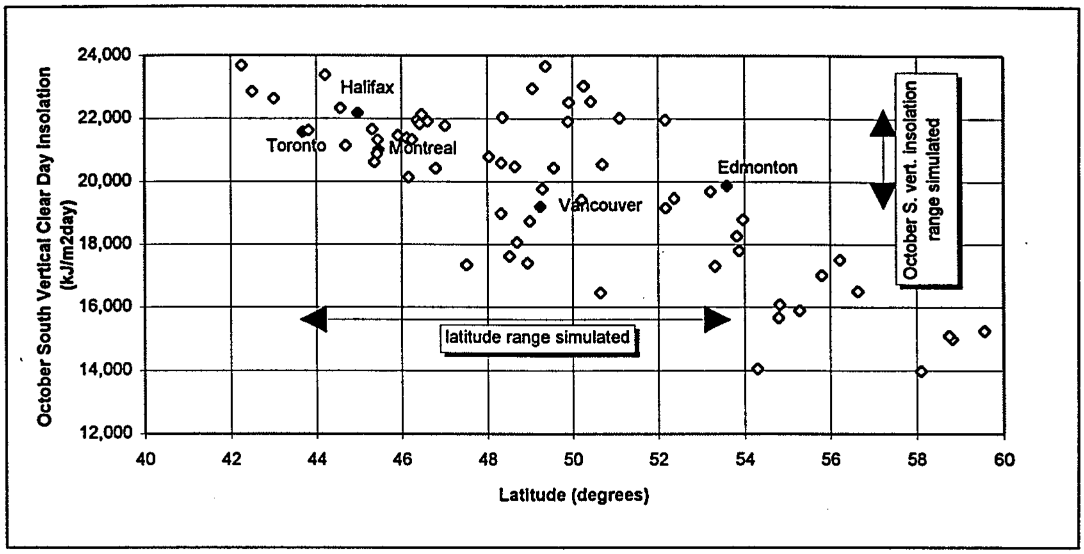
Figure 2.2 October Average Temperature vs Latitude (68 Canadian cities)



There are small variations (less than 1%) in recommended glazed area between regions. The small variation is due to the small range in temperatures and clear day insolation in the critical October month - in the five cities simulated (Table 2.4) and across Canada (Figures 2.2 and 2.3).

[17] Although October and April are both nominally "heating season" months and have similar average temperatures, ground temperatures are lower in April (higher ground heat loss). Also, clear day south vertical solar heat gain is lower in April because of higher sun angles. Finally, since August and April have the same sun angles, windows with ovehangs are more likely to be at least partially shaded in April than October (since overhangs are used to reduce summer overheating in August).

Figure 2.3 October Clear Day South Vertical Insolation vs Latitude
(68 Canadian cities)



Approximate October clear day 9AM to 6PM and full day energy balances are shown in Table 2.4, for a house with conventional construction and a relatively small amount of south glazing. Day-time gains exceed losses by a substantial and largely similar margin for all five cities. Excess gains must be stored in the thermal storage mass of the house to prevent overheating.

With a more efficient envelope and/or more south glazing, gains would exceed losses by an even greater margin.

Table 2.4 October Clear Day Energy Balance

Conventional house with 5% of floor area in south glazing & 17.4 kWh/day internal gains)

	Vancouver		Edmonton		Toronto		Montreal		Halifax	
	9AM-6PM	Day	9AM-6PM	Day	9AM-6PM	Day	9AM-6PM	Day	9AM-6PM	Day
Losses MJ	97	307	132	418	95	303	100	319	101	321
Gains:										
Internal MJ	23	63	23	63	23	63	23	63	23	63
Solar MJ	123	123	141	141	138	138	135	135	136	136
TOTAL MJ	146	186	164	204	161	201	158	198	159	199
Gains /Losses	**151%**	61%	**124%**	49%	**169%**	66%	**158%**	62%	**157%**	62%

Table 2.5 Maximum South Glazed Area to Avoid Excessive Overheating

Conservation level	Internal gains kWh/day	Mass level[1]	0.6m overhang[2]	0.9m overhang	1.2m overhang
			Maximum South glazed Area (% floor area)		
Normal	26.0	Low	5.1%	6.0%	7.0%
	26.0	Medium	6.3%	7.1%	7.8%
	26.0	High	8.1%	9.2%	10.2%
	17.4	Low	5.7%	6.8%	7.0%
	17.4	Medium	6.5%	7.6%	8.5%
	17.4	High	9.1%	10.2%	11.7%
	12.9	Low	6.5%	7.6%	8.5%
	12.9	Medium	8.2%	9.2%	10.4%
	12.9	High	10.1%	11.5%	13.7%
R-2000	26.0	Low	3.1%	3.6%	4.0%
	26.0	Medium	3.6%	4.1%	4.6%
	26.0	High	5.0%	5.5%	6.5%
	17.4	Low	3.9%	4.6%	5.5%
	17.4	Medium	4.9%	5.6%	6.5%
	17.4	High	6.5%	7.2%	8.1%
	12.9	Low	4.3%	5.0%	5.7%
	12.9	Medium	5.3%	6.1%	6.9%
	12.9	High	6.8%	7.6%	8.4%
Advanced	17.4	Low	2.8%	3.6%	4.4%
	17.4	Medium	3.6%	4.5%	5.3%
	17.4	High	5.0%	5.9%	6.7%
	12.9	Low	3.5%	4.3%	5.1%
	12.9	Medium	4.6%	5.4%	6.3%
	12.9	High	5.9%	6.7%	7.6%

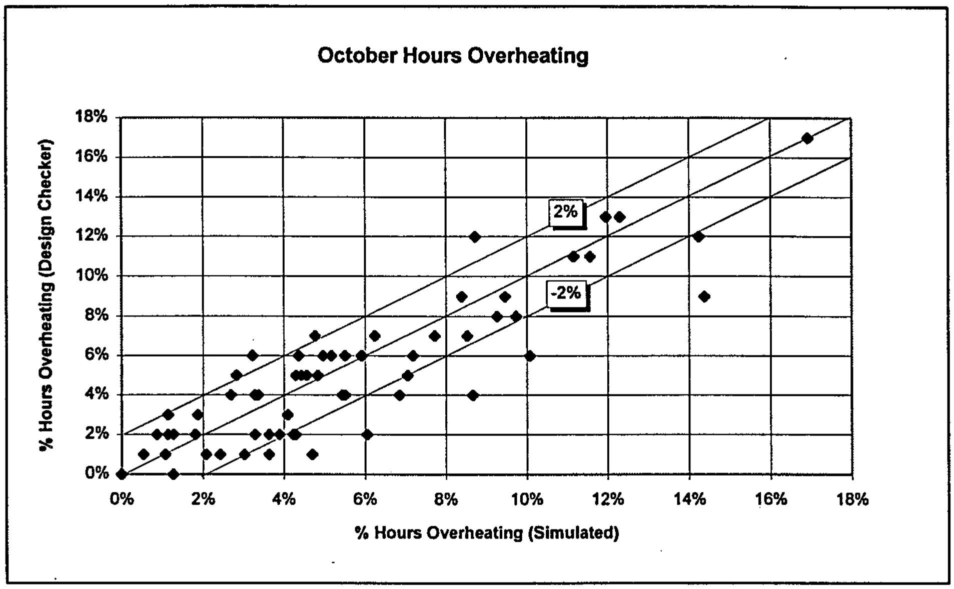
[1] Mass levels: Low - wood frame/gyproc; Medium - Low, but double gyproc; High - Medium plus concrete topcoat, some concrete walls

[2] Overhangs located 0.3m above south glazings

Errors associated with the results can be divided into two main types -

- errors associated with Suncode hourly simulations (section 2.5.2), and
- errors associated with simplifications in deriving the 'Rules of Thumb' in Table 2.5 from the simulation results. - within 2% of predicted hours of overheating for 81% of cases (Figure 2.4). This amounts to a difference in recommended south glazed area of less than 0.5% of the heated floor area.

Figure 2.4 Errors in Design Checker with respect to Simulation Results



Additional errors may occur if the Design Guidelines/Design Checker are used for conditions outside the range of conditions in the original simulations (see Figures 2.2 and 2.3). The simulations were performed for five cities across Canada with latitudes ranging from 43.7 degrees to 53.6 degrees. This range covers most of the major population centres in Canada.

The Design Guidelines apply only to overheating during the heating season in a heating dominant climate. Overheating during the summer would have to be taken care of through external shading, venting and/or mechanical cooling.

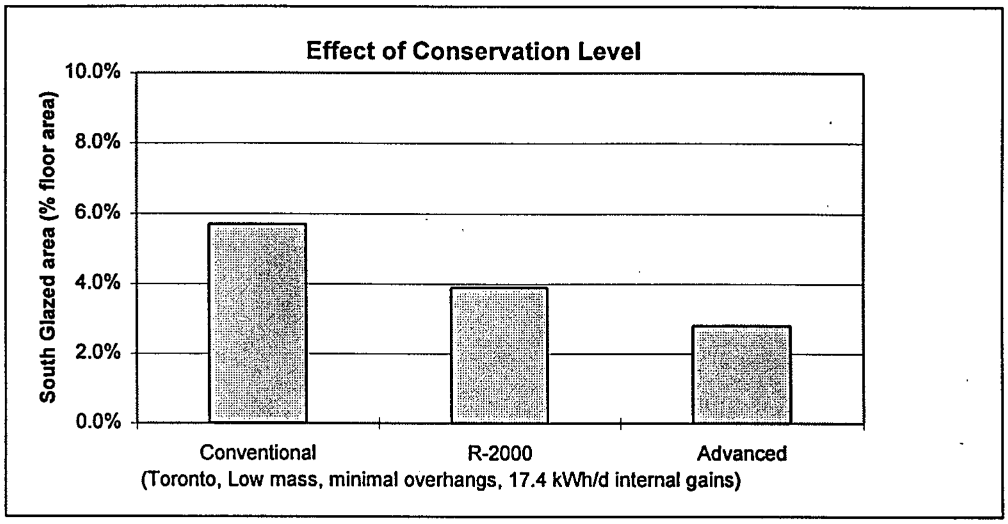
The values in Table 2.5 assume all south glazings are shaded with the overhang indicated (see Figures 2.10 to 2.12 for design options). With 0.3m overhangs on the second floor only, October hours of overheating increased approximately 1% (amounts to a reduction in recommended south glazed area of less than 0.3%).

The Design Checker predicted higher hours of overheating than measured for the monitored houses (Appendix C), but successfully predicted excessive overheating in the Yarrow and Edmonton houses, and acceptable levels of overheating for the Vancouver Healthy house. However, it predicted excessive overheating for the Ottawa house when the occupants reported none (the house was only occupied from March through August, however).

Some general findings include:

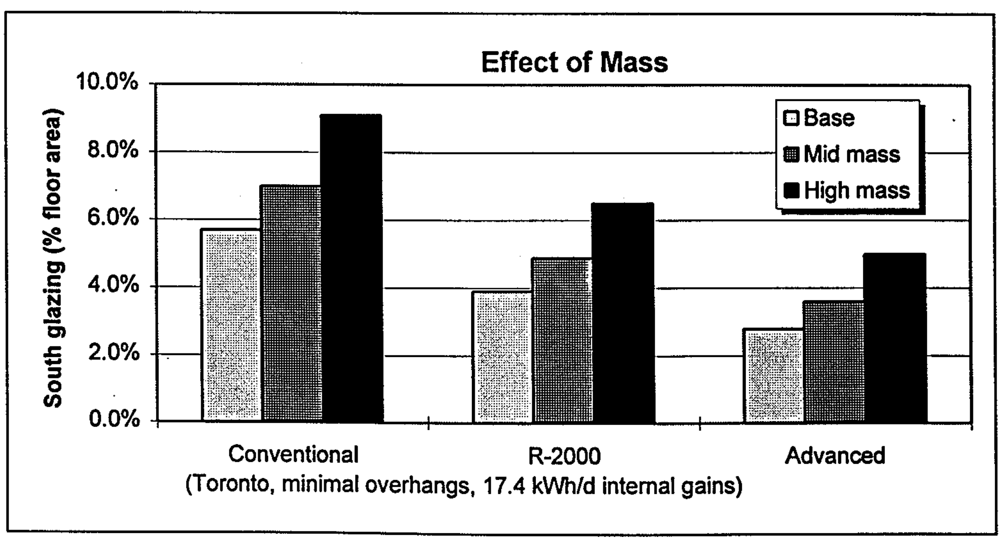
- October was found to be the critical heating season month for overheating for virtually every simulation run,
- recommended south glazed area is strongly dependant on conservation level - high levels result in severe restrictions to the amount of south windows that can be used without excessive overheating (Figure 2.5).

Figure 2.5 Effect of Conservation Level on Recommended Maximum South Glazed Area



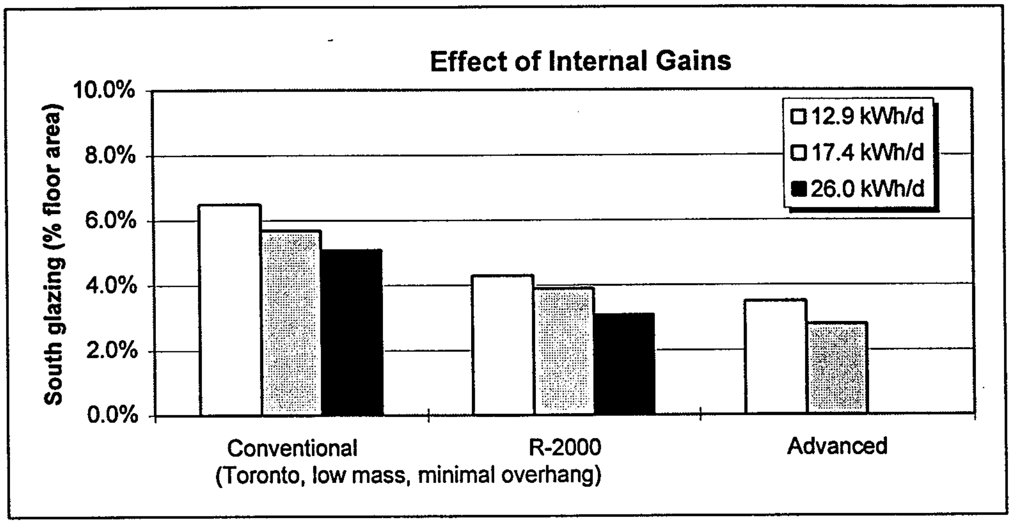
- adding more thermal storage mass allowed more south glazing to be added without increasing overheating, however at higher conservation levels, additional mass is slightly less effective at controlling overheating.

Figure 2.6 Effect of Thermal Storage Mass on Recommended Maximum South Glazed Area



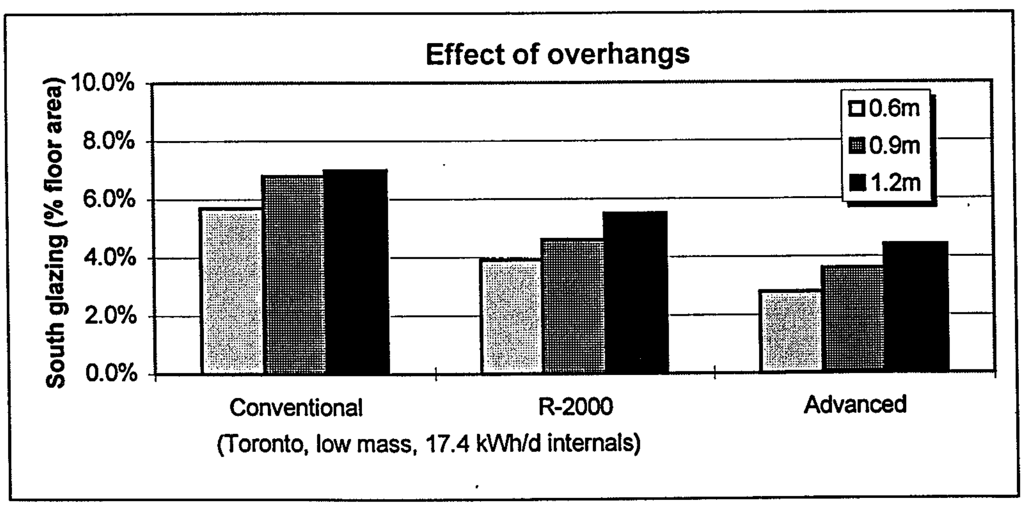
- changing to more efficient glazing resulted in slightly less overheating (typically about 1% fewer hours in October). The increased glazing thermal efficiency has a secondary effect on building total heat loss, but a primary effect on solar heat gain,
- increasing internal heat gains resulted in significant reductions in recommended south glazed area,

Figure 2.7 Effect of Internal Heat Gains on Recommended Maximum South Glazed Area



- increasing overhang allowed for additional south glazing. The ratio (height to overhang)/(overhang width) was found to be a critical factor in affecting winter overheating (Figures 2.8, 2.9),

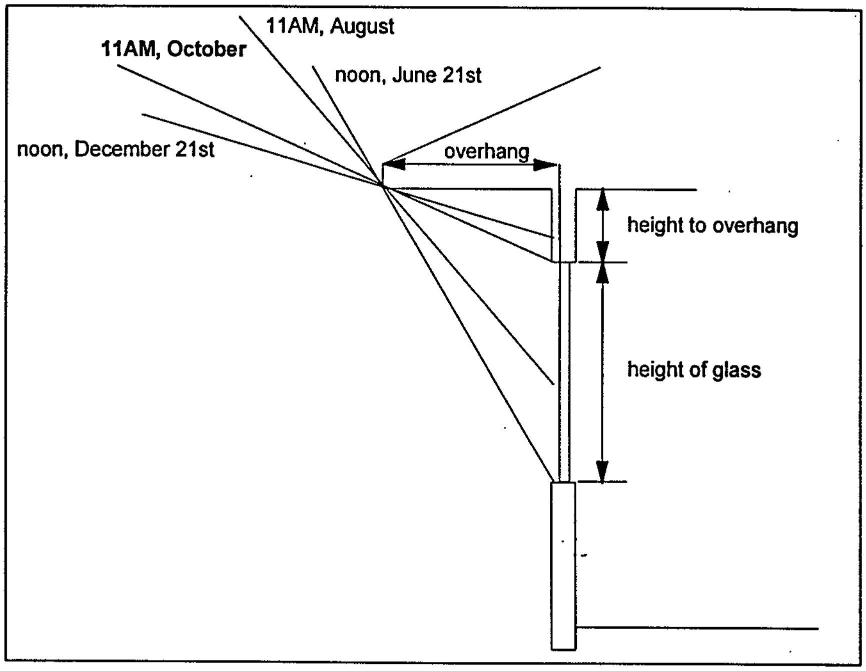
Figure 2.8 Effect of Overhang Width on Recommended South Glazed Area (0.3m height to overhang in all cases)



- summer overheating is affected by the ratio (window height plus height to overhang)/(overhang width). July and August are generally the critical cooling months, with August being the most difficult to control from a passive solar point of view since the sun angles are lower (equal to April).

Proper design of south window overhangs is critical to the prevention of overheating - winter and summer, as south window area increases.

Figure 2.9 Critical Sun Angles



Designing the overhang (width from glazing to front of overhang - typically the facia or gutter) and height to overhang (height of bottom of overhang above the top of the glass), so that the sun reaches to just touch the top of the glazing at 11AM in October, ensures minimal shading from 10AM to 2PM (~70% to 90% of insolation), from October through February - the critical space heating months (see Table 2.6). Using a larger height to overhang, or shorter overhang, results in less shading in March and April, but will also result in more severe summer overheating, since August and April have the same sun angles.

To reduce summer overheating, the ideal would be to make the glazing short enough that it would be fully shaded in August - however this is generally only practical with clerestory glazings, where view is not required. A less stringent requirement would be to fully shade the glazing at noon on June 21st (see Glass Height + Height to Overhang in Table 2.6) - at the expense of increased summer overheating, or cooling requirement.

Table 2.6 Location and Window Shading[18]

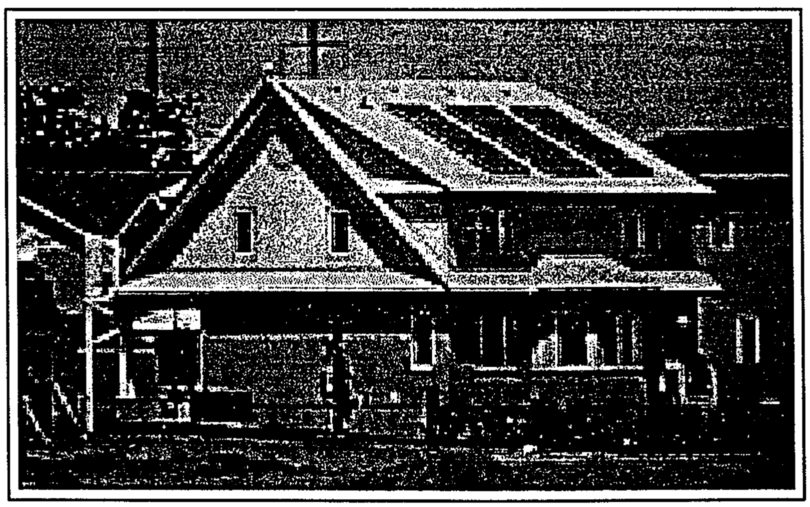
		0.3m overhang		0.6m overhang		0.9m overhang		1.2m overhang	
		Min. winter shading	Shade in June	Min. winter shading	Shade in June	Min. winter shading	Shade in June	Min. winter shading	Shade in June
Latitude (degrees)	Cities in Latitude Range	Height to Overhang[1] (m)	Glass + Height to Overhang[2] (m)	Height to Overhang (m)	Glass + Height to Overhang (m)	Height to Overhang (m)	Glass + Height to Overhang (m)	Height to Overhang (m)	Glass + Height to Overhang (m)
42 to 44	Toronto	0.2	0.8	0.4	1.6	0.6	2.4	0.8	3.3
44 to 46	Ottawa, Montreal, Halifax	0.2	0.7	0.4	1.5	0.6	2.2	0.8	3.0
46 to 48	St. John's, Moncton	0.2	0.6	0.4	1.3	0.6	2.0	0.7	2.7
48 to 50	Vancouver, Winnipeg	0.2	0.5	0.3	1.2	0.5	1.8	0.6	2.4
50 to 52	Calgary, Regina	0.2	0.4	0.3	1.1	0.5	1.7	0.6	2.2
52 to 54	Edmonton, Saskatoon	0.1	0.4	0.3	1.0	0.4	1.5	0.5	2.0

[1] Height to overhang to result in minimal shading between 10AM and 2PM from October to February

[2] Height from bottom of glazing to underside of overhang for glazing to be fully shaded on June 21st (38% to 45% shaded in August - Toronto to Edmonton, respectively (other locations between)

Ideally, all south glazings should be optimally shaded by overhangs. With traditional "box" designs, only the upper floor glazings are shaded by the roof overhang, however a number of design options allow for the shading of glazings on lower floors (Figures 2.10 to 2.12).

Figure 2.10 Shading of South Windows - Main and Second Floor (Ottawa Advanced House)



[18]Values are approximate for range of latitude. More accurate values available with *House Comfort Design Checker* (see Appendix C)

Figure 2.11 Shading of South Windows - Main Floor (Manitoba Advanced House) - using projected second floor or small deck

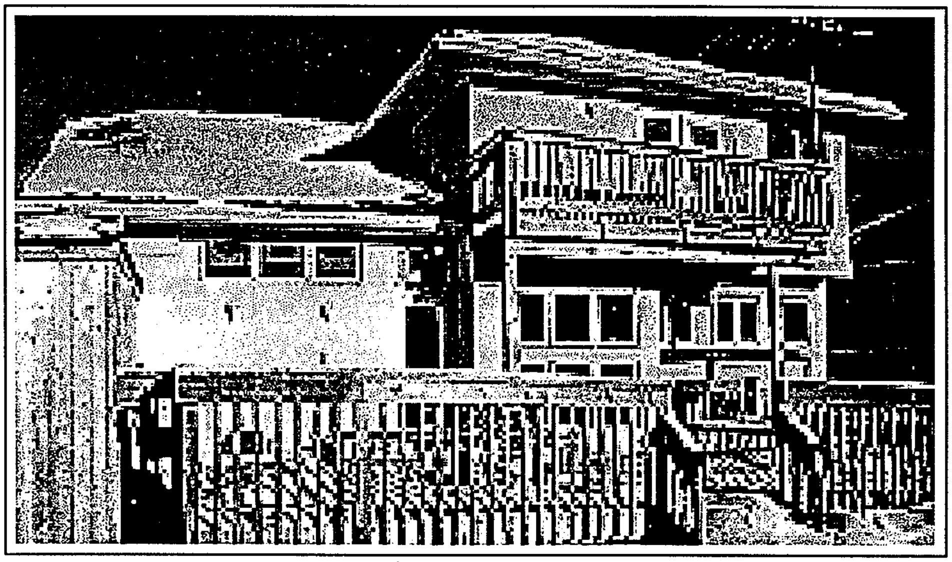
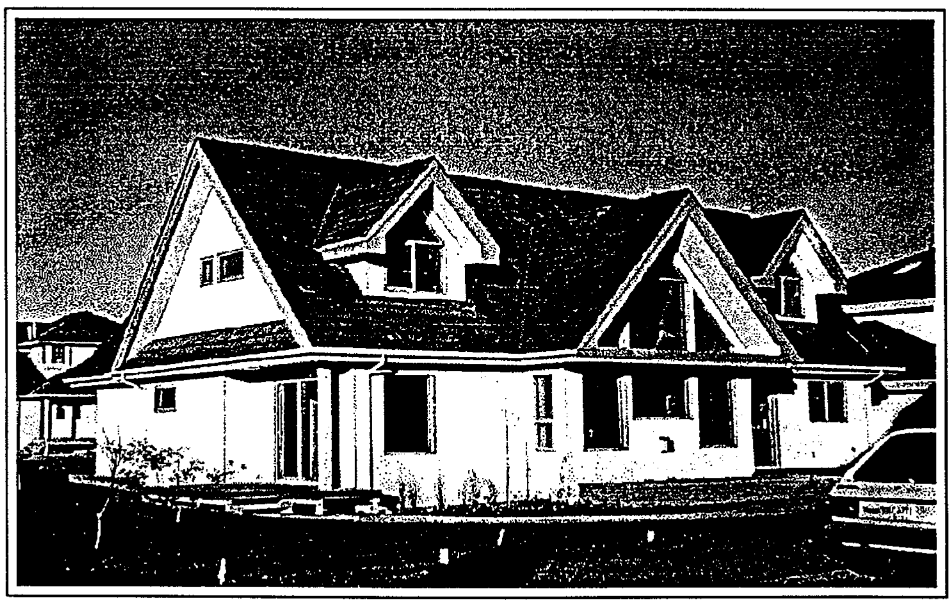


Figure 2.12 Shading of South Windows - Main and Second Floor (B.C. Advanced House) - a change in the dormer roof slope orientation would improve the shading characteristics of the second floor overhangs.



2.7 House Comfort Design Checker

Since detailed computer analysis becomes feasible only at the later stages of the design, when the building has been fully defined, the 'Rules of Thumb' developed in section 2.6 were incorporated into a spreadsheet to facilitate their use.

Sample input/output sheets for the *House Comfort Design Checker* spreadsheet software are included in Appendix C. Most of the design rules and recommendations from the *Passive Solar Techniques for Canadian Housing* are incorporated into the spreadsheet software. The designer can then use the spreadsheet to perform the calculations required for using the "Rules of Thumb" at the conceptual design phase of passive solar design. It provides guidance and recommendations to ensure the the resulting design does not result in excessive overheating.

A Vancouver group of designers evaluated the software in draft form, and their comments were incorporated into the final software. These included:

- more documentation to explain purpose and limitations of software,
- reorganize layout so that left-right scrolling is not required on some systems,
- "open up" input/output sheet to make it more readable,
- use digital inputs for percentages, rather than decimal values, and
- determine effect of multiple low-E coatings and incorporate into spreadsheet

Recommendations that were not incorporated because they were outside the scope of this project, included:

- output from CAD drawings into the software, and
- effect of West glazings on summer overheating.

The *House Comfort Design Checker* spreadsheet allows for simple inputs that include the following:

- house location (selected from a pre-defined set),
- heated floor area,
- south, east and west glazing areas,
- south shading overhang dimensions,
- external shading amount (trees, buildings, etc.)
- mass level (descriptive - three levels),
- energy conservation level (descriptive - three levels),
- level of internal gains (descriptive - three levels),
- heating system type (forced air or liquid/direct heating), and

The output includes:

- recommendations for maximum glazed area to avoid overheating, while optimizing energy performance,
- severity of fall overheating,
- recommendations for suitable shading devices (depending on orientation),
- recommendations for design improvements.

2.8 (Modified) Computer Software for Use in the Residential Design Process

At the **conceptual stage** of design, the *House Comfort Design Checker* spreadsheet software, discussed in section 2.7, can be used. Additional hourly simulations could improve its accuracy and range of applicability (including summer overheating guidelines). Also, more complete documentation would make it easier for the first-time user.

At the **sketch/detailed stage** of design, a modified HOT-2000 could be used to predict overheating as well as heating and cooling energy use. If the overheating algorithms currently in use (modified version 6), were extended to cover the full year, instead of only the summer as is presently the case, it would be suitable for the task. The survey results from this study should also be built into the program outputs, so that it would predict the percentage of hours in each month that exceeded the heating setpoint plus 4C.

Current version 7 features should be built into the program and a complete overhaul of the inputs and outputs should be undertaken to improve "user friendliness".

At the **detailed design stage** of design, modified versions of either Enerpass or Suncode would be suitable for optimization of extreme passive solar designs. Both of these hourly simulation programs currently require considerable "tuning" to achieve reasonable results. Also, some simplifications are built-in, which make the Enerpass program, in particular, less suitable for passive solar simulations.

The Suncode program is currently only suitable for use by researchers, as it is simply too "user hostile" for general use by residential designers[19]. The following are some recommendations for changes that would be required if the Suncode program were to be used at the detailed design phase:

Calculation methods -

- Ground heat loss calculation needs to be improved - currently below grade losses are calculated to a single ground node (also, ground temperatures must be scheduled by the user, as they are not part of the weather file). Either the Mitalas empirical coefficients (as used in HOT-2000), or a built-in network of nodes would be acceptable,

[19] Even relatively minor changes required by the parametric analysis required over one hour for each run to set up, run, output and analyze the results - even with a considerable amount of Excel spreadsheet analysis software.

- Modelling of infiltration needs to be changed to allow for the input of fan-door test coefficients,
- A variety of mechanical heating and cooling systems should be modelled - currently only heating and cooling demand are calculated, so fuel consumption must calculated by the user with fixed efficiency factors. Modelling should be fairly simple, since the program already performs its calculations on a time-step less than one hour,
- The program should also model heat recovery ventilators, as currently the user must calculate and input factors that result in ventilation and heat loss equivalent to an HRV,
- Modelling of glazings should be improved - currently the program models simple, multiple-glazed systems using the glass extinction coefficients and manually input thermal resistance factors. No provision is made for low-E coatings, films, etc.,

Inputs and Outputs -

- An overall control interface is required to transparently run the three modules currently used - EDITS (input), LOADS (calculation), and VIEW (output). Currently these are run individually from the DOS prompt.
- The program requires a "user-friendly" front end to take the place of the EDITS module for building input. Ideally, this would have a graphic input, but at least would do away with the line editor input used now. If both Suncode and HOT-2000 were modified for use by designers, the ideal would be to make the building file format readable by both programs, so that the user does not have to enter the data twice,
- The VIEW module should be debugged and enhanced to allow for a standard report instead of the currently used Output function that simply dumps results to the screen - not all of which is always visible,

With all its need for improvements, the Suncode program does have some characteristics that make it uniquely suitable for modelling residential passive solar systems - a task for which it was specifically designed.

3 CONCLUSIONS and RECOMMENDATIONS

Some of the findings from this study include:

- occupants advised that temperatures 4C above "normal" for more than 4% of the hours in a month or season constituted excessive overheating. These findings should be verified with a larger survey - including U.S. sources, for example,
- existing residential simulation software require an overhaul to their input/output to be useful to designers. HOT-2000 should be modified to include overheating algorithms used earlier - extended to cover the heating season,
- existing hourly simulation software is able to predict overheating, but requires technical expertise to formulate inputs and to interpret outputs,
- excessive solar overheating can be prevented if the design guidelines developed in this study are adhered to. These guidelines include recommended maximum south glazed area, based on -
    - conservation level,
    - internal heat gains,
    - thermal storage mass, and
    - window overhang size and placement

Other factors affecting overheating include placement of windows, placement of thermal storage, use of carpets and placement of furnishings.

4 APPENDIX:

- A: Monitored House Survey
- B: Hourly Simulation Outputs
  1. Monitored Houses
  2. Parametric Hourly Simulation Outputs
- C: Design Checker Outputs - Monitored Houses

APPENDIX A: Monitored Houses

		Location		Report	House Info		Conservation	Hourly Monitoring Data					Contact for Monitoring Data		Remarks
		BC			Plans	Takeoff	Level:	Source	Start	Duration	Type:	Data format:			
		AB			available	Data	1=Passive				Continuous	Aeolian (tape)			
		SA				available	2=Advanced				Intermittent	HP85 (tape)			
		MA					3=R2000				Spot	Campbell (tape)			
		etc.					4=Nrgy Eff					PC (disk)			
							5=Standard					other			
					(Yes/No)	(Yes/No)	6=Test Huts			(mo)					
Code	Region	Prov.	City	ReportSource	Plans	Takeoff	ConsLevel	DataSource	SDate	Duration	MonType	DataFormat	DataContact	Phone	Remarks
Short list of suitable houses for which data is available:															
Healthy	BC	BC	Vancouver	SAR/CMHC	yes	yes	3	SAR	Feb-94	15	Continuous	PC	Ken Cooper	604-525-2239	loft level windows not openable; occupants report some overheating
CCDH	PR	AB	Edmonton	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	most glazing on upper floor; bb electric; 8% of summer hours > 26C
OTWA	ON	ON	Ottawa	SAR	Yes	Yes	2	SAR	Sep-94	12	Continuous	PC	Ken Cooper	604-525-2239	12% of summer hours greater than 26C
YAROW	BC	BC	Yarrow	SAR/NRC	yes	no	3	SAR	Dec-82	18	Continuous	HP85 tape	Ken Cooper	604-525-2239	incompatible hourly data format, however statistical analysis sufficient
N.Van.	BC	BC	N. Vancouver	SAR/NRC	yes	yes	4	SAR	Nov-84	12	Continuous	HP85 tape	Ken Cooper	604-525-2239	incompatible hourly data format, however statistical analysis sufficient
NOVT	QU	PQ	Montreal	SAR	Yes	Yes	2	SAR	May-94	12	Continuous	PC	Ken Cooper	604-525-2239	Dino Gerbassi, Siricon, has done an overheating analysis on house
TUNS	MT	NS	Halifax	TUNS	Yes	Yes	3	TUNS	Jun-89	12	Continuous	PC	Ismet Ugursal	902-420-7542	
Houses with data requiring some additional work:															
KURI	PR	AB	Edmonton	HME	Yes	No	4	HME	Jul-84	12	Continuous	PC	Wil Mayhew	403-484-0476	
LAKE	PR	AB	Edmonton	HME	Yes	No	4	HME	Jul-84	12	Continuous	PC	Wil Mayhew	403-484-0476	
BEAR	PR	AB	Edmonton	HME	Yes	No	4	HME	Jul-84	12	Continuous	PC	Wil Mayhew	403-484-0476	
BERG	PR	AB	Edmonton	HME	Yes	No	4	HME	Jul-84	12	Continuous	PC	Wil Mayhew	403-484-0476	
Houses with data requiring considerable additional work and/or unsuitable houses:															
MANT	PR	MA	Winnipeg	SAR	Yes	Yes	2	SAR	Sep-94	12	Continuous	PC	Ken Cooper	604-525-2239	11% of summer hours greater than 26C; occupants complaining of overheating
APCH	QU	PQ	Boucherville	SAR	Yes	Yes	2	SAR	Jun-94	12	Continuous	PC	Ken Cooper	604-525-2239	unoccupied
RVDL	PR	AB	Edmonton	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	6% of summer hours greater than 26C
TORO	ON	ON	Toronto	Ontario MOE	Yes	Yes	3	BLP	Sep-85	36	Continuous	PC	Paul Duffy	905-886-9393	**unable to obtain response from consultant**
SUDB	ON	ON	Sudbury	Ontario MOE	Yes	Yes	3	BLP	Sep-85	36	Continuous	PC	Paul Duffy	905-886-9393	**unable to obtain response from consultant**
CATH	ON	ON	St. Catherines	Ontario MOE	Yes	Yes	3	BLP	Sep-85	36	Continuous	PC	Paul Duffy	905-886-9393	**unable to obtain response from consultant**
KING	ON	ON	Kingston	Ontario MOE	Yes	Yes	3	BLP	Sep-85	36	Continuous	PC	Paul Duffy	905-886-9393	**unable to obtain response from consultant**
BCMIN1	BC	BC	Richmond	SAR/BCMEMP	no	no	4	SAR	Oct-82	7	Continuous	**HP85 tape**	Ken Cooper	604-525-2239	part of set of 3 houses (reference, conserver, solar): **incompatible data format**
BCMIN2	BC	BC	Saanich	SAR/BCMEMP	no	no	4	SAR	Jan-83	4	Continuous	**HP85 tape**	Ken Cooper	604-525-2239	part of set of 3 houses (reference, conserver, solar): **incompatible data format**
KITSUN	BC	BC	Vancouver	SAR/NRC	no	no	1	SAR	Jun-79	12	Continuous	**HP85 tape**	Ken Cooper	604-525-2239	**incompatible data format**
LOGAN	BC	BC	Vancouver	SAR	no	no	1	SAR		12	Continuous	**HP85 tape**	Ken Cooper	604-525-2239	**incompatible data format**
BCAH	BC	BC	Vancouver	SAR	Yes	Yes	2	SAR	Sep-94	12	Continuous	PC	Ken Cooper	604-525-2239	**unoccupied; significant shading of main floor glazings**
SASK	PR	SK	Saskatoon	SAR	Yes	Yes	2	SAR	Sep-94	12	Continuous	PC	Ken Cooper	604-525-2239	**minimal south glazing**
MORN	PR	AB	Edmonton	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	**wood heat estimated at 13% of total space heating**
WSGV	PR	AB	Edmonton	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	**minimal wood stove use; shaded; minimal south glazing**
PSVE	PR	SK	Saskatoon	Sesci 78	No	No	1	SRC	Feb-76	**3 days**	Continuous	**Paper form**	Rob Dumont	306-933-6216	**incompatible data format**
CONS	PR	SK	Regina	Sesci 78	Yes	No	1	SRC	Feb-76	**3 days**	Continuous	**Paper form**	Rob Dumont	306-933-6216	**incompatible data format**
FLAIR	PR	MN	Winnipeg	Proskiw Eng.	Yes	Yes	3	Proskiw Eng.	Mr,Oc 86	Au, Oc 87	Continuous	**Strip Charts**	Gary Proskiw	204-633-1107	**incompatible data format**
DWORN	PR	AB	Lethbridge	CISTI	No	No	1	**Report only - data no longer available**					NOT AVAILABLE		**data not available**
WEDG1	ON	ON	Oakville	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	**Air conditioning**
WEDG2	ON	ON	Oakville	SAR	Yes	Yes	3	SAR	May-89	12	Continuous	PC	Ken Cooper	604-525-2239	**Air conditioning**
WTLO	ON	ON	Waterloo	SAR	Yes	Yes	2	SAR	Jul-94	12	Continuous	PC	Ken Cooper	604-525-2239	
CARP	ON	ON	Carp	SAR	Yes	Yes	3	SAR	May-89	15	Continuous	PC	Ken Cooper	604-525-2239	**wood stove rarely used, but unmonitored**
LORRI	ON	ON	Ballinafad	Enermodal	Yes	No	1	Enermodal	Mar-89	**5 days**	Continuous	PC	John Kokko	519-743-8777	**Require a day of time to retrieve; only 5 days hourly data**
BOWER	ON	ON	Ottawa	CISTI	No	No	1	Scanada	Jan-83	12	Continuous	**Aeolian (tape)**	Ken Ruest	613-236-7179	**incompatible data format**
BRAMP	ON	ON	Waterloo	NRCan	Yes	No	2	Enermodal	Jun-90	24	Spot	**Paper form**	John Kokko	519-743-8777	**All hourly data lost; only paper info remaining in report and at Enermodal**
SOLAR	ON	ON	Kingston	CISTI			1	Oliver-Drerup-White				**Aeolian (tape)**			**Large wood heating component**
CHBLY	QU	PQ	Chambly	SAR	Yes	Yes	3	SAR	May-88	12	Continuous	PC	Ken Cooper	604-525-2239	**Large wood heating component**
LAURIN	QU	PQ	Montreal	CISTI			1	Memphramagog Community Technology Group							**data not available**
QUTEST	QU	QU	Montreal	Concordia			6						Dr. Andreas Athienitis	514-848-8791	Looked at many passive solar heating and overheating in Level A test huts
UATEST	PR	AB	Edmonton	U of A	Yes	Yes	6	U of A	Jun-80	12 years	Continuous	**Various**	Mark Ackerman	403-492-2822	Looked at many passive solar heating and overheating in **Level A test huts**
NSAH	MT	NS	Halifax	SAR	Yes	Yes	2	SAR	May-94	12	Continuous	PC	Ken Cooper	604-525-2239	**Large wood heating component, temperature measured**
SOLNS1	MT	NS	Halifax	No Report	Yes	No	1	Solar NS	Jan-92	4	Continuous	PC	Don Roscoe	902-852-3789	**Both SOLNS houses are high mass, slab heat storage, and high glazing**
SOLNS2	MT	NS	Halifax	No Report	Yes	No	1	Solar NS	Jan-92	4	Continuous	PC	Don Roscoe	902-852-3789	**which apparently do not overheat. Reluctant to share data.**
WILSON	MT	PEI	Hunt River	CISTI	No	No	1	**Report only - data no longer available**					Rob Brandon	613-992-2958	**hourly data not available**
URI	MT	PEI	Charlottetown	Rob Brandon	Yes	Yes	2	**Report only - data no longer available**					Rob Brandon	613-992-2958	**hourly data not available**

APPENDIX A: Monitored Houses

	Description			Foundation	Mass	Glazings		Solar Type	Solar Gains							Shading			Mechanical systems:				
	Heated floor area	Heated volume	Storeys	Type: bsmt, unhtd c/s, htd c/s, slab	Level: A, B, C (as H2K)	Total glazed area	Average RSI	Direct, Indirect (trombe), Isolated (sunspace)	Direct: area SE,S,SW -vertical	SE,S,SW -sloped	E/W vertical	Indirect: area SE,S,SW	Isolated: area SE,S,SW	Ratio of south glazing to floor areas	External	Type: trees, buildings	Self shading: overhang, coatings, side fins	Space heating: Main fuel: Gas, Oil, Electricity, Wood	Type	Distribution: Forced Air, Baseboard, Radiant	Wood heat: Fireplace, Stove	Space Cooling
	(m2)	(m3)				(m2)			(m2)	(m2)	(m2)	(m2)	(m2)	(%)	(%)							(Yes/No)
Code	FloorArea	Volume	Storeys	Foundation	Mass	TotalGlass	RSIg	Solartype	DvSglass	DsSglass	DEWglas	InGlass	IsGlass	GlazRatio	ExtShade	ShadeType	Shading	SpHtFuel		SpHtDist	Wood	SpCool
Short list																						
Healthy	137	334	2.5	slab	A		0.51	Direct	7.6	0.0		0.0	0.0	5.5%	30%	buildings	overhang	gas	ondensin	forced air	n/a	no
CCDH	171	509	1	bsmt	A	19.3	0.55	Direct	10.2	0.0		0.0	0.0	6.0%	0%		overhang	gas	medium	baseboard	n/a	no
OTWA	261	680	2	bsmt	A	26.3	0.93	Direct	13.7	0.0		0.0	0.0	5.2%	10%	trees/bldgs.	overhang	gas	ondensin	forced air	n/a	yes
YAROW	205	663	2	unhtd c/s	B	30	0.55	Direct	19.0	0.0		0.0	0.0	9.3%	25%	mountain	overhang	gas	medium	forced air	n/a	no
N.Van.	276	969	2.5	bsmt	B	60	0.35	Isolated	6.8	0.0		0.0	34.7	15.0%	10%	trees/bldgs.	overhang	gas	nv.+damp	forced air	stove	no
NOVT	222	602	2.5		A	46.7	0.93	Direct	26.7	0.0		0.0	0.0	12.0%	10%	trees/bldgs.	overhang	electric	gs hp	forced air	n/a	yes
TUNS	213	532	3	bsmt	A		0.34	Direct		0.0		0.0	0.0		10%	trees/bldgs.	overhang	electric	hp	forced air	n/a	yes
Houses																						
KURI																						
LAKE																						
BEAR																						
BERG																						
Houses																						
MANT	279	722	2	bsmt	A	26.8	1.3	Direct	16.3	0.0		0.0	0.0	5.8%	5%	trees/bldgs.	overhang	gas	ondensin	forced air	n/a	no
APCH	182	535	3		A	12.5	0.51	Direct	8.8	0.0		0.0	0.0	4.8%	10%	trees/bldgs.	overhang	electric	gs hp	forced air	n/a	yes
RVDL	220	585	2	bsmt	A	31.3	0.45	Direct	12.5	0.0		0.0	0.0	5.7%	0%		overhang	gas	medium	forced air	n/a	no
TORO																						
SUDB																						
CATH																						
KING																						
BCMIN1	211		2	slab	B		0.50	Isolated	13.0	0.0		0.0	14.0	12.8%	10%	trees/bldgs.	overhang	gas/elect.	conv.	forced air	fireplace	no
BCMIN2	197		2	slab	B		0.55	Direct	16.0	0.0		0.0	12.0	14.2%	10%	trees/bldgs.	overhang	elect.	furnace/bb	forced air	fireplace	no
KITSUN	818		3	unhtd c/s	B		0.40	Indirect		34.6		94.5	0.0	15.8%	10%	trees/bldgs.	overhang	elect.	baseboard	baseboard	n/a	no
LOGAN																						
BCAH	270	844	2	unhtd c/s	A	40.9	0.81	Direct	22.9	0.0		0.0	0.0	8.5%	40%	buildings	overhang	gas	ondensin	forced air	n/a	yes
SASK	339	852	2	bsmt	A	30.6	1.04	Direct	13.4	0.0		0.0	0.0	4.0%	10%	trees/bldgs.	overhang	gas	ondensin	forced air	n/a	no
MORN	324	856	2	bsmt	A	42.7	0.42	Direct	11.0	0.0		0.0	0.0	3.4%	0%		overhang	gas	medium	forced air	fireplace	no
WSGV	310	805	2.5	bsmt	A	25.9	0.43	Direct	2.3	0.0		0.0	0.0	0.7%	60%	trees/bldgs.	overhang	gas	medium	forced air	stove	no
PSVE																						
CONS																						
FLAIR																						
DWORN																						
WEDG1																						
WEDG2																						
WTLO	263	729	1	bsmt	A	26.4	0.90	Direct	15.6	0.0		0.0	0.0	5.9%	10%	trees/bldgs.	overhang	gas	integ./hrv	forced air	n/a	no
CARP	202	644	1.5	slab	A	22.0	0.55	Direct	9.3	0.0		0.0	0.0	4.6%	0%		overhang	electric	baseboard	baseboard	stove	no
LORRI																						
BOWER																						
BRAMP																						
SOLAR																						
CHBLY																						
LAURIN																						
QUTEST																						
UATEST																						
NSAH																						
SOLNS1																						
SOLNS2																						
WILSON																						
URI																						

APPENDIX A: Monitored Houses

	Airtightness		Operation		
			Number of occupants	Internal gains	
		(cm2)		(kWh/d)	
Code	ACH50	ELA	Occ	Internals	Notes
Short list					
Healthy	3.4	582	3	24.7	rental property: 2 sets of occupants
CCDH	1.06	137	4	16.7	live-in basement;
OTWA	1.03	228	3	10.9	
YAROW	1.77	413	3	22.0	concrete top coat on main floor (quarry tile on most)
N.Van.	4.08	1405	3	19.7	4 day graphical profiles in report; heat exchanger on less than 10% of winter hours
NOVT	1.32	63	0		
TUNS	<1.5		2		house faces SW
Houses					
KURI					
LAKE					
BEAR					
BERG					
Houses					
MANT	0.78	223	2	22.8	
APCH	0.91	201	0		
RVDL	0.79	190	3	40.7	high internal gains
TORO					MOE houses:
SUDB					Full Level B monitoring using Sciemetric
CATH					Part of a 22 house R2000 monitoring program
KING					
BCMIN1	4.4		3	29.5	fireplace used 8 times; humidistat controlled ventilation fan: incompatible data format
BCMIN2	4.4		5	22.2	fireplace used 4 times; heat exchanger ventilation: incompatible data format
KITSUN				16/unit	8 unit townhouse: 1 unit direct gain; rest trombe wall + direct gain: data format
LOGAN					no plans; indirect solar; incompatible data format
BCAH	1.4	470	0	14.2	
SASK	0.95	304	3	26.6	
MORN	1.35	453	6		unknown internal base load since electric water heater included
WSGV	1.06	208	2	44.3	
PSVE					Detailed heat loss calculations done; cooling test carried out; both houses in SESCI 78
CONS					SESCI 78 Proceedings, Passive Solar Heaing Results from 2 Sask. Houses
FLAIR					Four, 1 month periods for 10 to 19 houses, requires manually input from charts
DWORN					
WEDG1					
WEDG2					
WTLO	0.68	182	5	20.0	
CARP	0.68		2	18.2	
LORRI					
BOWER					
BRAMP					spot data; incompatible data format
SOLAR					
CHBLY					
LAURIN					
QUTEST					
UATEST					
NSAH					wood heating
SOLNS1					data unobtainable
SOLNS2					data unobtainable
WILSON					Rob was consultant on Wilson house but no longer has info on it. He does,
URI					however, have the report and other documentation on URI house.

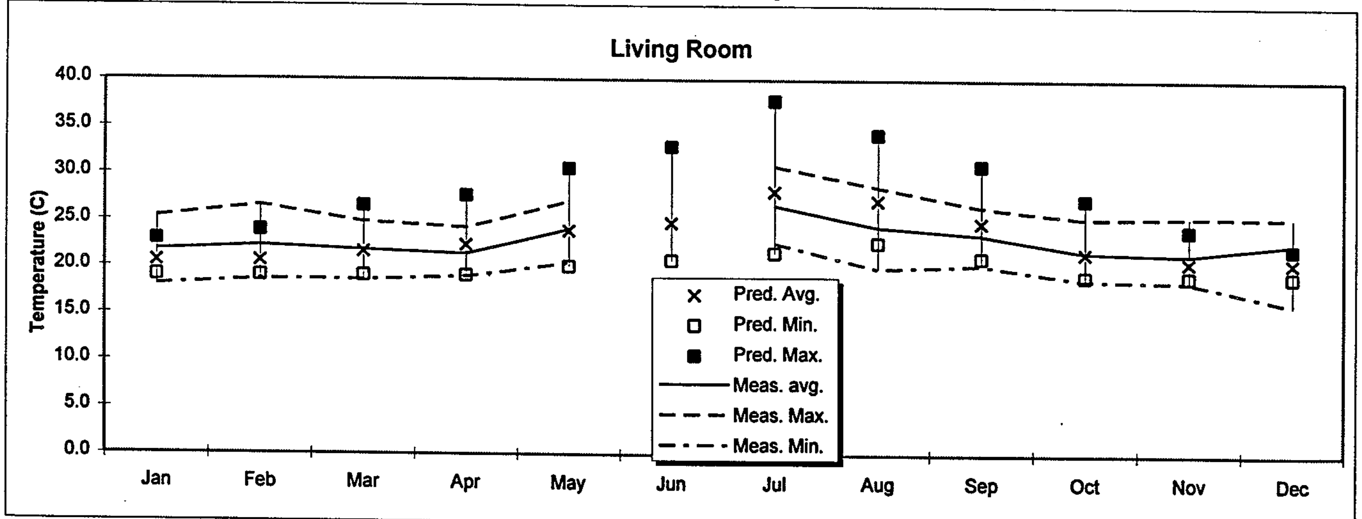
VANCOUVER HEALTHY HOUSE

Enerpass predicted vs Measured (1994/95)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<<< summer >>>>>>>>>>>>>>>>>>>>								
Bedroom Temp. (C)														
Predicted	avg.	19.3	19.4	20.1	21.2	22.9	24.1	27.0	26.0	23.7	20.6	19.9	19.6	20.0
Measured	avg.	18.3	19.3	19.4	19.7	23.0		26.0	23.6	22.9	21.1	19.7	20.0	19.6
Predicted	min	16.1	16.3	16.4	17.0	18.5	20.0	20.6	21.8	19.7	17.0	16.5	16.6	16.1
Measured	min	14.2	16.3	16.3	16.7	18.9		21.7	17.0	20.5	17.5	17.3	15.6	14.2
Predicted	max	22.7	22.6	25.0	25.9	28.9	31.7	36.1	33.1	29.1	25.0	22.9	22.6	25.9
Measured	max	21.9	23.4	23.0	24.0	26.5		30.3	28.8	26.6	26.6	23.9	23.3	26.6
Living room Temp. (C)														
Predicted	avg.	20.6	20.6	21.6	22.3	23.9	24.8	28.2	27.2	24.8	21.6	20.6	20.5	21.1
Measured	avg.	21.8	22.3	21.8	21.4	24.1		26.7	24.4	23.5	21.7	21.4	22.7	21.9
Predicted	min	19.0	19.0	19.0	19.0	20.0	20.7	21.5	22.6	21.0	19.0	19.0	19.0	19.0
Measured	min	18.0	18.6	18.6	18.9	20.4		22.6	19.9	20.3	18.7	18.5	16.1	16.1
Predicted	max	22.9	23.9	26.5	27.6	30.5	32.9	37.8	34.2	30.9	27.3	24.0	22.0	27.6
Measured	max	25.4	26.6	24.9	24.2	27.0		30.9	28.7	26.5	25.3	25.5	25.4	26.6
Hours >23.9C:**														
Predicted	hrs	0	0	81	145	315	388	661	657	413	73	1	0	300
Measured (adj.)	hrs	59	116	39	4	457		673	452	260	57	21	148	444
	%	8%	17%	5%	1%	61%		90%	61%	36%	8%	3%	20%	9%
Hours >25.9C:														
Predicted	hrs	0	0	8	32	128	180	500	456	195	8	0	0	48
Measured (adj.)	hrs	0	4	0	0	55		449	106	23	0	0	0	4
	%	0%	1%	0%	0%	7%		60%	14%	3%	0%	0%	0%	0%
Total Hours:														
Predicted		744	672	744	720	744	720	744	744	720	744	720	744	5088
Measured		736	672	739	718	363		490	743	720	744	717	744	5070

* overheating threshold 4C above mean heating season living room temperature (occupants complained that bedroom was too cold)

** assuming clear day stratification of ~2C, the loft would overheat when the living room was warmer than 23.9C.



Note: Measured average temperature during October to April 21.9C (living room) and 19.6C (bedroom).
Predicted average temperature during October to April 21.1C (living room) and 20.0C (bedroom).

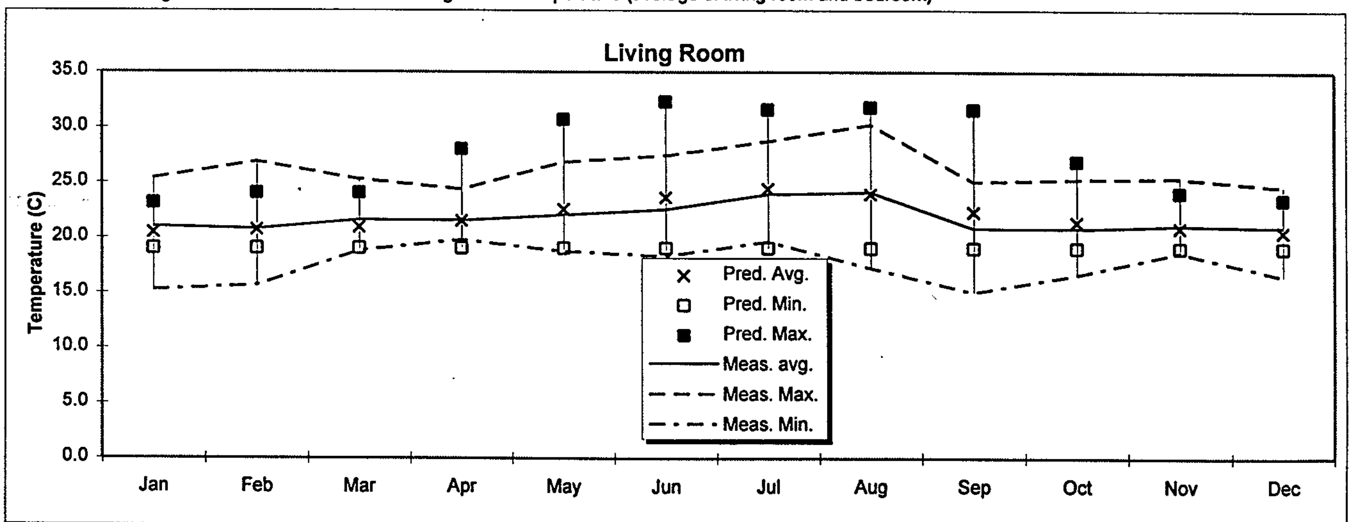
Loft exceeded discomfort threshold of 25.9C (23.9C in living room) for more than 4% of the hours (measured and predicted).
Living room exceeded discomfort threshold of 25.9C for less than 4% of the hours (measured and predicted).

EDMONTON COLD CLIMATE R-2000 HOUSE

Enerpass predicted vs Measured

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer				>>>>>>>>>>>>>>>>>>>>				
Basement Bedroom Temp. (C)														
Predicted	avg.	20.8	20.4	20.3	20.6	21.6	22.6	23.3	22.9	21.4	20.7	20.4	20.7	20.6
Measured	avg.	19.0	18.8	19.4	19.3	20.5	20.7	22.0	22.8	19.1	19.2	19.3	19.5	19.2
Predicted	min	18.9	18.6	18.5	18.7	19.0	19.3	19.2	19.0	18.8	18.9	18.9	19.1	18.5
Measured	min	16.8	17.3	17.6	16.9	18.2	17.5	18.9	16.8	14.4	16.6	17.4	18.0	16.6
Predicted	max	23.3	23.2	22.9	25.3	27.3	28.9	28.1	28.4	27.2	24.8	22.8	22.9	25.3
Measured	max	20.5	23.8	21.0	21.0	23.2	24.0	25.3	27.0	24.1	21.1	21.2	21.7	23.8
Family room Temp. (C)														
Predicted	avg.	20.5	20.7	20.9	21.5	22.6	23.6	24.4	23.9	22.3	21.4	20.9	20.5	20.9
Measured	avg.	21.0	20.8	21.6	21.5	22.1	22.6	23.9	24.1	20.9	20.8	21.1	20.9	21.1
											bdrm + living room average:			20.2
Predicted	min	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Measured	min	15.3	15.7	18.8	19.8	18.8	18.4	19.7	17.3	15.1	16.7	18.7	16.5	15.3
Predicted	max	23.1	24.0	24.0	28.0	30.7	32.3	31.6	31.8	31.8	26.9	24.0	23.4	28.0
Measured	max	25.4	26.9	25.3	24.4	26.9	27.5	28.8	30.3	25.1	25.3	25.4	24.6	26.9
Family room Hours >24.2C*:														
Predicted	hrs	0	0	0	31	103	187	292	243	86	26	0	0	57
Measured (adj.)	hrs	7	35	24	12	71	120	293	352	23	8	9	5	100
	%	1%	5%	3%	2%	10%	17%	39%	47%	3%	1%	1%	1%	2%
Total Hours:														
Predicted		744	672	744	720	744	720	744	744	720	744	720	744	5088
Measured		743	672	743	240	742	720	708	744	720	743	706	744	4591

* overheating threshold 4C above mean heating season temperature (average of living room and bedroom)



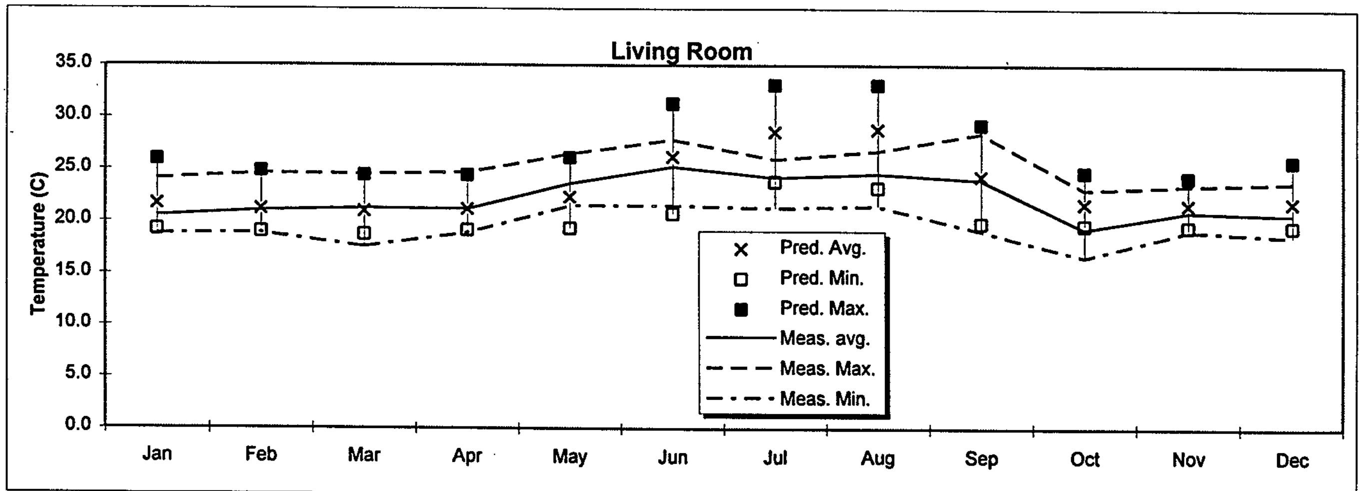
Note: Measured average temperature during October to April 21.1C (family room) and 19.2C (bedroom).
Predicted average temperature during October to April 20.9C (family room) and 20.6C (bedroom).
Family room exceeded discomfort threshold of 24.2C for more than 4% of the hours - spring month (measured and predicted).

OTTAWA ADVANCED HOUSE

Enerpass predicted vs Measured

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer >>>>>>>>>>>>>>>>>>>>								
Basement Temp. (C)														
Predicted	avg.	20.7	20.9	21.2	21.9	23.5	27.8	30.3	30.5	25.6	22.5	21.6	20.6	21.3
Measured	avg.	19.4	19.3	19.2	19.8	22.2	23.9	23.2	23.8	23.1	19.0	20.2	19.8	19.5
Predicted	min	19.0	19.0	19.0	19.0	19.0	20.9	23.8	23.0	19.3	19.0	19.0	19.0	19.0
Measured	min	17.2	16.2	15.7	18.2	20.3	21.2	21.5	21.4	19.4	17.0	18.4	16.2	15.7
Predicted	max	24.2	25.9	25.5	27.8	28.3	34.4	35.8	36.1	32.8	27.5	27.6	24.1	27.8
Measured	max	21.8	21.4	21.8	21.6	24.4	25.9	24.0	25.4	25.2	21.5	21.8	21.6	21.8
Family room Temp. (C)														
Predicted	avg.	21.7	21.2	21.0	21.2	22.3	26.2	28.6	28.9	24.3	21.7	21.6	21.9	21.5
Measured	avg.	20.6	21.0	21.3	21.1	23.6	25.2	24.2	24.6	24.0	19.3	21.0	20.7	20.7
Predicted	min	19.2	19.0	18.7	19.1	19.3	20.7	23.8	23.2	19.8	19.6	19.5	19.5	18.7
Measured	min	18.8	18.9	17.6	18.9	21.5	21.5	21.3	21.5	19.1	16.6	19.1	18.6	16.6
Predicted	max	25.9	24.8	24.4	24.4	26.1	31.3	33.1	33.1	29.3	24.7	24.2	25.8	25.9
Measured	max	24.1	24.6	24.5	24.7	26.5	27.9	26.0	26.8	28.5	23.1	23.5	23.8	24.7
Hours >24.7C:														
Predicted	hrs	6	1	0	0	53	622	709	702	277	0	0	10	17
Measured (adj.)	hrs	0	0	0	0	125	460	176	300	214	0	0	0	0
	%	0%	0%	0%	0%	17%	64%	24%	40%	30%	0%	0%	0%	0%
		0%	0%	0%	0%	0%	24%	42%	37%	0%	0%	0%	0%	0%
Total Hours:														
Predicted		744	672	744	720	744	720	744	744	720	744	720	744	5088
Measured		744	672	744	720	744	719	736	744	504	645	456	741	4722

* overheating threshold 4C above mean heating season family room temperature



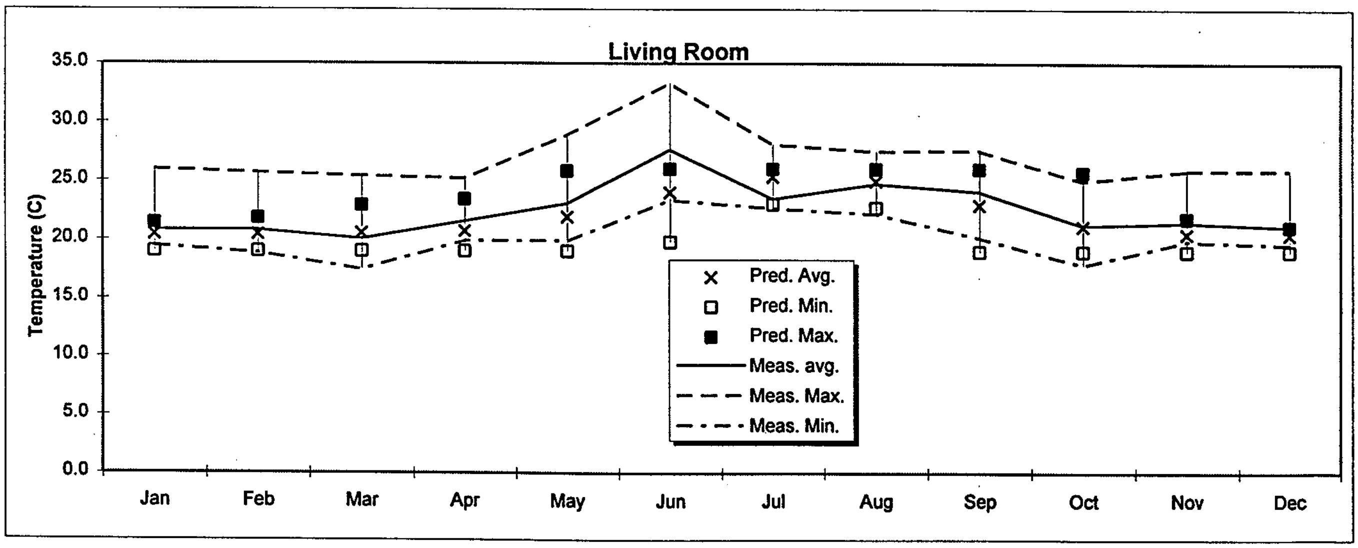
Note: Measured average temperature during October to April 20.7C (family room) and 19.5C (basement).
Predicted average temperature during October to April 21.5C (family room) and 21.3C (basement).
Family room exceeded discomfort threshold of 24.7C for less than 4% of the heating season hours (measured and predicted).

MONTREAL NOVTEC ADVANCED HOUSE

Enerpass predicted vs Measured

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer >>>>>>>>>>>>>>>>>>>>								
With GSHP Air Conditioning (C)														
Predicted	avg.	20.4	20.4	20.6	20.7	21.9	24.0	25.4	25.0	23.0	21.2	20.5	20.4	20.6
Measured -														
Kitchen (south)	avg.	20.8	20.8	20.1	21.6	23.1	27.7	23.5	24.8	24.1	21.3	21.5	21.1	21.0
M.Bdrm (south)	avg.	21.1	19.7	20.2	21.6	23.2	28.0	23.5	24.6	24.0	20.6	19.8	19.5	20.4
Bdrm. (north)	avg.	19.6	18.0	18.9	20.4	22.4	27.4	23.2	24.0	23.0	19.5	18.5	18.2	19.0
Dining (north)	avg.	21.4	20.6	20.0	21.6	22.8	27.0	22.7	24.1	23.7	20.9	21.3	21.4	21.0
												House average		20.4
Predicted	min	19.0	19.0	19.0	19.0	19.0	19.8	23.0	22.7	19.0	19.0	19.0	19.0	19.0
Measured -														
Kitchen (south)	min	19.5	18.9	17.5	19.9	19.9	23.4	22.7	22.2	20.2	17.9	19.9	19.6	17.5
M.Bdrm (south)	min	19.7	17.8	18.1	20.6	19.7	23.4	22.7	21.8	19.4	17.3	17.6	17.7	17.3
Bdrm. (north)	min	17.4	15.6	16.3	18.5	19.0	22.7	21.9	21.3	18.4	16.4	16.0	15.9	15.6
Dining (north)	min	20.2	18.9	17.8	20.6	19.9	21.3	20.6	21.5	20.1	17.9	20.0	19.9	17.8
Predicted	max	21.4	21.8	22.9	23.4	25.8	26.0	26.0	26.0	26.0	25.7	21.8	21.1	25.7
Measured														
Kitchen (south)	max	26.0	25.7	25.4	25.2	28.9	33.3	28.1	27.5	27.6	25.0	25.9	25.9	26.0
M.Bdrm (south)	max	24.8	25.2	24.3	24.3	29.9	33.5	28.9	27.3	27.3	24.1	23.8	24.5	25.2
Bdrm. (north)	max	21.6	21.6	22.7	22.8	29.0	33.0	28.6	27.1	26.0	23.1	21.3	21.5	23.1
Dining (north)	max	23.4	23.2	23.4	23.5	27.8	32.3	27.7	26.7	26.2	23.2	23.5	24.1	24.1
Hours >24.4C*:														
Predicted (house)	hr.	0	0	0	0	50	319	649	531	146	12	0	0	12
Meas. (Kitchen)	hr.	28	29	24	30	190	690	8	328	254	21	55	35	222
	%	4%	4%	3%	4%	26%	96%	1%	44%	35%	3%	8%	5%	4%
Cooling on	%	1%	4%	5%	1%	4%	14%	35%	17%	5%	5%	4%	1%	3%
Total Hours:														
Predicted		744	672	744	720	744	720	744	744	720	744	720	744	5088
Measured		743	548	744	720	744	718	136	701	720	733	720	744	4952

* threshold 4C above mean heating season temperature



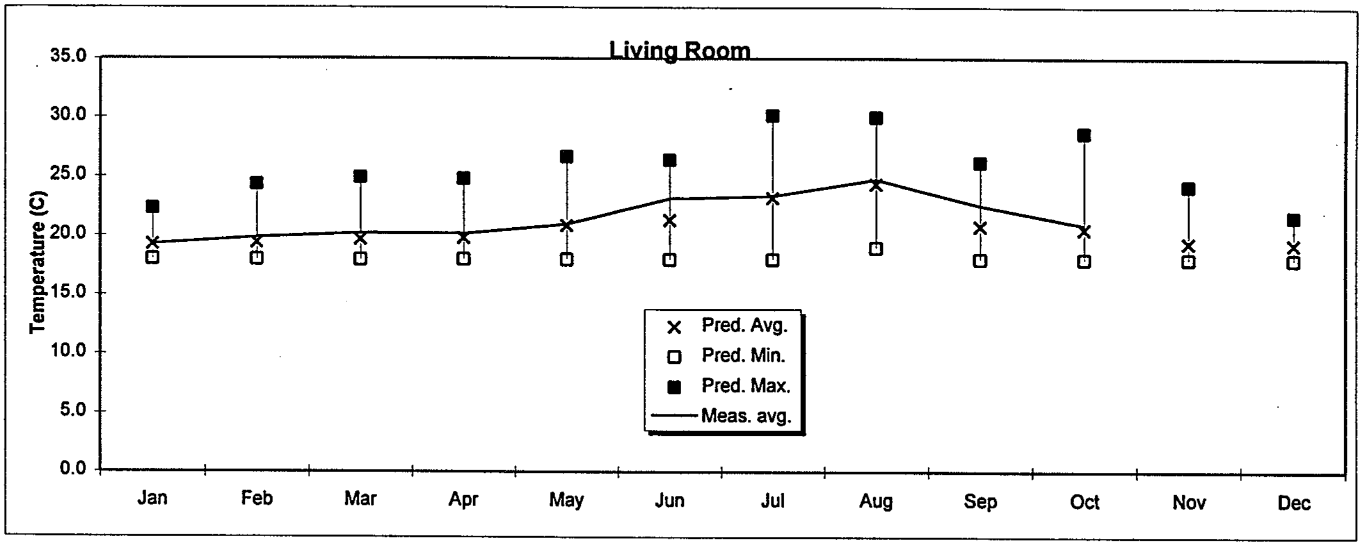
Note: Measured house average temperature during October to April 20.4C
Predicted house average temperature during October to April 20.6C
Kitchen exceeded discomfort threshold of 24.4C for more than 4% of the heating season hours (measured).
Most of house rarely exceeded the discomfort threshold of 24.4C (see maximum temperatures) during the heating season (measured and predicted).

YARROW Passive Solar House

Suncode TMY predicted vs Measured (1983/84)

		Jan	Feb	Mar	Apr	<<<<<<<<<<<< summer >>>>>>>>>>>>>>>>>>> May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
Inside Temp. (C)														
Predicted	avg.	19.3	19.5	19.7	19.8	20.9	21.3	23.2	24.4	20.8	20.6	19.4	19.3	19.6
Measured	avg.	19.3	19.9	20.3	20.2	21.0	23.2	23.4	24.8	22.6	20.9		18.6	19.9
Predicted	min	18.0	18.0	18.0	18.0	18.0	18.0	18.0	19.0	18.0	18.0	18.0	18.0	18.0
Predicted	max	22.3	24.3	24.9	24.8	26.7	26.4	30.2	30.0	26.2	28.7	24.2	21.6	28.7
Hours >23.9C*:														
Predicted		0	2	13	9	66	74	295	414	62	80	1	0	105
Measured (adj.)		5	29	22	5		72	170	212	118	48		0	109
% of hours		1%	4%	3%	1%		10%	23%	28%	16%	6%		0%	2%
Total Hours:														
Measured		744	672	744	720	744	720	744	744	720	744		744	4368

* threshold 4C above mean heating season temperature



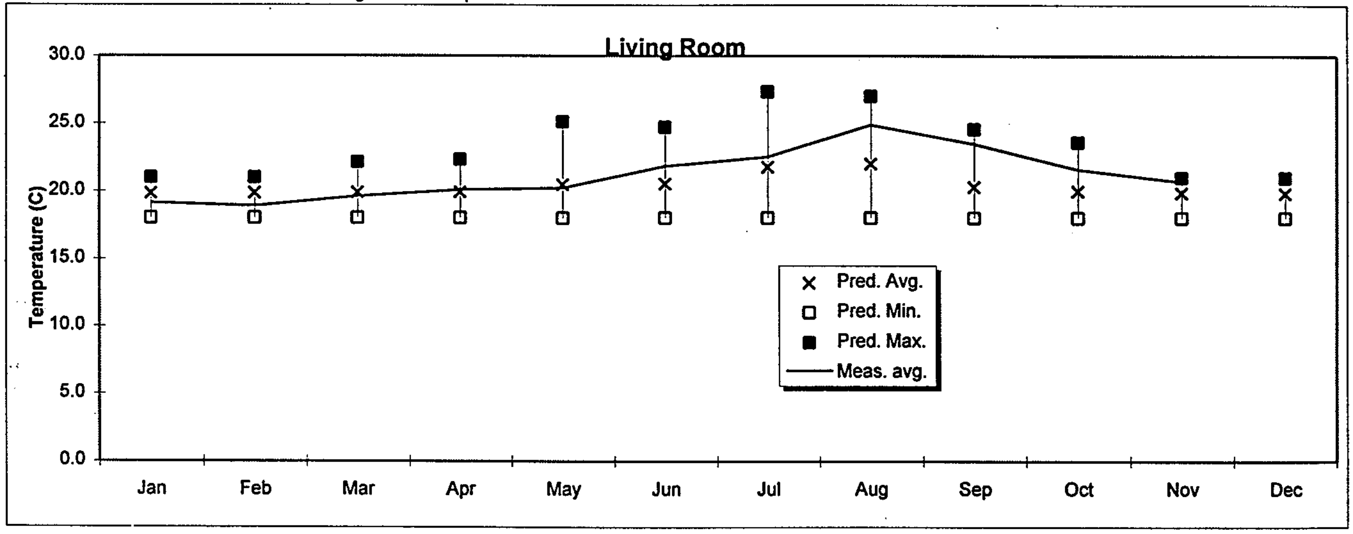
Note: Measured house average temperature during October to April 19.9C
Predicted house average temperature during October to April 19.6C
House exceeded discomfort threshold of 23.9C for more than 4% of the hours - October (measured and predicted).

N. VANCOUVER Passive Solar House

Suncode TMY predicted vs Measured (1985)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer >>>>>>>>>>>>>>>>>>>>>								
Sunspace Temp. (C)														
Predicted	avg.	14.1	16.9	18.6	20.8	25.1	25.4	29.1	30.2	24.5	21.2	16.2	13.8	17.3
Measured	avg.	12.0	12.9	14.2	15.6	19.3	20.4	23.5	21.0	20.0	*16.8*		11.7	13.8
Predicted	min	9.0	12.8	12.9	13.5	17.4	18.4	18.0	20.1	15.6	14.2	13.5	8.9	8.9
Measured	min	6.5	6.3	6	7.8	11.5	11.7	13.0	11.5	10.2	*8.5*		6.8	6.0
Predicted	max	26.3	29.6	32.6	34.4	38.4	37.6	41.4	42.5	39.6	35.4	28.7	25.4	35.4
Measured	max	17.5	19.5	22.3	23.4	27.0	29.0	34.0	30.5	29.7	*25.0*		16.5	25.0
Inside Temp. (C)														
Predicted	avg.	**19.9**	**19.9**	**19.9**	**20.0**	20.5	20.6	21.8	22.0	20.3	**20.0**	**19.9**	**19.9**	**19.9**
Measured	avg.	**19.1**	**18.9**	**19.7**	**20.1**	20.3	21.9	22.6	24.9	23.5	**21.6**	**20.7**		**20.0**
Predicted	min	**18.0**	**18.0**	**18.0**	**18.0**	18.0	18.0	18.0	18.0	18.0	**18.0**	**18.0**	**18.0**	**18.0**
Predicted	max	**21.0**	**21.0**	**22.1**	**22.3**	25.1	24.7	27.4	27.0	24.6	**23.6**	**21.0**	**21.0**	**23.6**
Hours >24C*:														
Predicted		**0**	**0**	**0**	**0**	14	14	125	138	3	**0**	**0**	**0**	**0**
Measured (adj.)		**28**	**0**	**3**	**11**	6	92	146	520	273	**6**	**1**		**50**
% of hours		4%	0%	0%	2%	1%	13%	20%	70%	38%	1%	0%		1%
Total Hours:														
Measured		744	672	744	720	744	720	744	744	720	744	720		4344

* threshold 4C above mean heating season temperature



Note: Measured house average temperature during October to April 20.0C
Predicted house average temperature during October to April 19.9C
House exceeded discomfort threshold of 24.0C for 4% or less of the hours in each month (measured and predicted).

APPENDIX B.2 Parametric Hourly Simulation Outputs

Parametric hourly simulations were performed, using Suncode, on a house with 141.8 m^2 main and upper floor area, and a 74.0 m^2 heated basement.

		Above Grade: Ceiling RSI	Walls RSI	Windows[1] RSI	Basement below grade walls RSI	Floor perimeter RSI	Floor center RSI	HRV[2]
Vancouver								
	Conventional	5.8	2.3	0.4/0.5	0.8	none	none	
	R-2000	7.2	4.4	0.5/0.9	1.9	1.8	none	Yes
	Advanced	10.0	4.4	0.9	1.9	1.8	1.8	Yes
Edmonton								
	Conventional	7.2	3.1	0.5	0.8	none	none	
	R-2000	10.0	4.4	0.5/0.9	1.9	1.8	1.8	Yes
	Advanced	10.0	4.4	0.9	2.9	1.8	1.8	Yes
Toronto								
	Conventional	7.2	3.1	0.5	0.8	none	none	
	R-2000	7.2	4.4	0.5/0.9	1.9	1.8	none	Yes
	Advanced	10.0	4.4	0.9	2.9	1.8	1.8	Yes
Montreal								
	Conventional	7.2	3.1	0.5	0.8	none	none	
	R-2000	7.2	4.4	0.5/0.9	1.9	1.8	none	Yes
	Advanced	10.0	4.4	0.9	2.9	1.8	1.8	Yes
Halifax								
	Conventional	7.2	3.1	0.5	0.8	none	none	
	R-2000	7.2	4.4	0.5/0.9	1.9	1.8	none	Yes
	Advanced	10.0	4.4	0.9	2.9	1.8	1.8	Yes

[1] Various window types for different scenarios

[2] Ventilation and Infiltration: Total 0.3 ac/h average for October

The following simulation outputs are a sampling of about 70 runs performed to determine the sensitivity of overheating to a variety of parameters, including south window area, conservation level, internal heat gains, thermal storage mass and overhang dimensions.

APPENDIX B.2

Passive Solar Direct Gain House

ID: TDR03L13
0.6m overhangs

Suncode TMY predicted
Toronto, Ontario
Forced air heat distribution
15.5 kW max. demand
Vent.: FA + HRV <60L/s
Total ac/h: 0.27 (Oct)
No air conditioning

Heated Floor Area	215.8 m2
Volume	548.3 m3
Heat Loss	197 W/C
	0.9 W/m2 floor.C
Mass	17.7 MJ/C total (incl. 25mm conc.)
	82 kJ/m2 floor.C
	2.7 MJ/m2 S.glass C

Internal Gains	17.4 kWh/d
Temperature setpoints	21.0 C (day), 18.0 C (night)
venting	25.0 C (windows opened - summer only)

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	2.2 m2	3.3% of floor area	2.2 m2	0.9 m2	1.7 m2	7.0 m2	4%
Main floor	2.1 m2	2.8% of floor area	2.7 m2	0.0 m2	1.2 m2	6.0 m2	3%
Basement	2.2 m2	3.0% of floor area	0.8 m2	0.0 m2	0.0 m2	3.1 m2	4%
TOTAL	6.6 m2	3.1% of total floor area	5.7 m2	0.9 m2	3.0 m2	16.1 m2	
						7.5% of total floor area	

Glazing: ER = -12.3 SHGC = 0.52 RSI = 0.52
summer shading with curtains; no skyline shading

Ground albedo 0.40 winter (0.2 summer)

Ambient		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer	>>>>>>>>	>>>>>>>>	>>>>>>>>					
Outside temp.	C	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8	6.8
Ground temp.	C	5.1	5.8	7.8	10.9	13.9	16.2	17.1	16.4	14.2	11.3	8.2	5.9	11.1
Horiz. Insolation	MJ/m2d	6.6	7.3	15.0	17.0	21.3	22.8	21.7	20.1	13.1	9.5	5.1	4.7	13.7
Energy:			Tg =		10.88	15.59 (summer)					11.27	6.56 (winter)		
Losses:														
Windows	GJ	-2.3	-1.8	-1.8	-1.3	-0.8	-0.6	-0.6	-0.6	-0.6	-0.9	-1.2	-2.0	-14.5
Other above grade	GJ	-4.3	-3.3	-3.4	-2.3	-1.4	-0.9	-0.9	-0.9	-1.1	-1.7	-2.3	-3.7	-26.2
to ground	GJ	-2.6	-2.3	-2.6	-1.8	-1.3	-1.9	-1.9	-1.9	-1.3	-1.9	-2.5	-2.6	-24.6
Infiltration	GJ	-3.4	-2.5	-2.4	-1.5	-0.8	-0.5	-0.5	-0.5	-0.5	-0.9	-1.4	-2.6	-17.3
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.2	-0.1	0.0	0.0	0.0	-0.8
Total	GJ	-12.5	-9.9	-10.2	-6.8	-4.4	-4.0	-4.1	-4.1	-3.6	-5.5	-7.3	-10.8	-83.3
Heating:														
Solar Gains	GJ	2.0	1.7	3.2	2.9	2.1	2.2	2.1	2.1	1.6	2.5	1.5	1.6	25.6
Internal Gains	GJ	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	22.8
Space heating	GJ	8.5	6.5	5.1	2.1	0.3	0.0	0.0	0.0	0.1	1.0	3.9	7.3	34.8
Total	GJ	12.5	9.9	10.2	6.8	4.4	4.1	4.1	4.0	3.6	5.4	7.3	10.8	83.1
Net Window gain	GJ	-0.2	-0.1	1.3	1.6						1.6	0.3	-0.4	4.1
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.2	-0.1	0.0	0.0	0.0	-0.8
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-0.5	-0.5	-0.5	-0.5	-0.6	0.0	0.0	0.0	-2.5

Temperatures		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>	>>>>>>>>	>>>>>>>>					
2nd floor	avg.	20.0	20.1	20.3	20.9	22.5	25.8	26.9	26.4	23.8	21.6	20.5	20.1	20.5
Main floor	avg.	20.1	20.2	20.4	21.0	22.7	25.9	27.0	26.4	23.9	21.8	20.6	20.2	20.6
Basement	avg.	20.1	20.2	20.2	20.6	22.1	25.0	26.1	25.6	23.3	21.2	20.4	20.2	20.4
Average		20.1	20.1	20.3	20.8	22.4	25.6	26.7	26.1	23.7	21.6	20.5	20.2	20.5
2nd floor	min	18.0	18.0	18.0	18.0	18.2	21.3	22.7	21.9	19.6	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.0	18.5	21.3	22.9	22.3	19.7	18.0	18.0	18.0	18.0
Basement	min	18.0	18.0	18.0	18.3	19.2	21.6	23.5	22.5	20.1	18.6	18.2	18.0	18.0
2nd floor	max	22.0	22.9	24.9	24.9	28.2	31.5	31.1	30.9	28.0	26.2	24.4	24.0	26.2
Main floor	max	21.9	22.9	24.4	24.9	28.4	31.8	31.1	31.1	28.2	26.0	23.9	23.5	26.0
Basement	max	21.0	21.1	22.0	22.6	25.9	29.2	29.0	28.7	26.3	23.7	22.3	21.8	23.7

Temperataure >25C:						<<<<<<<<<<<< summer	>>>>>>>>	>>>>>>>>	>>>>>>>>					
2nd floor	hrs	0	0	0	0	78	471	642	540	221	25	0	0	25
	%	0%	0%	0%	0%	10%	65%	86%	73%	31%	3%	0%	0%	0%
Main floor	hrs	0	0	0	0	82	492	659	559	230	15	0	0	15
	%	0%	0%	0%	0%	11%	68%	89%	75%	32%	2%	0%	0%	0%
Basement	hrs	0	0	0	0	21	354	600	491	67	0	0	0	0
	%	0%	0%	0%	0%	3%	49%	81%	66%	9%	0%	0%	0%	0%

Notes:

APPENDIX B.2

Passive Solar Direct Gain House

ID: TDR06H13
0.6m overhangs

Suncode TMY predicted
Toronto, Ontario
Forced air heat distribution
21.2 kW max. demand
Vent.: FA + HRV <60L/s
Total ac/h: 0.27 (Oct)
No air conditioning

Heated Floor Area	215.8 m2	
Volume	548.3 m3	
Heat Loss	202 W/C	
	0.9 W/m2 floor.C	
Mass	38.5 MJ/C total (incl. 25mm conc.)	
	178 kJ/m2 floor.C	
	3.0 MJ/m2 S.glass C	
Internal Gains	17.4 kWh/d	
Temperature setpoints	21.0 C (day),	18.0 C (night)
venting	25.0 C (windows opened - summer only)	

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	4.3 m2	6.3% of floor area	2.2 m2	0.9 m2	1.7 m2	9.1 m2	6%
Main floor	4.4 m2	6.0% of floor area	2.7 m2	0.0 m2	1.2 m2	8.3 m2	6%
Basement	4.2 m2	5.7% of floor area	0.8 m2	0.0 m2	0.0 m2	5.1 m2	5%
TOTAL	12.9 m2	6.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	22.5 m2	

Glazing: ER = -12.3 SHGC = 0.52 RSI = 0.52
summer shading with curtains; no skyline shading

10.4% of total floor area
Ground albedo 0.40 winter (0.2 summer)

Ambient		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>						
Outside temp.	C	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6	9.1
Ground temp.	C	5.1	5.8	7.8	10.9	13.9	16.2	17.1	16.4	14.2	11.3	8.2	5.9	11.1
Horiz. Insolation	MJ/m2d	2.3	4.8	8.3	13.7	19.8	18.4	24.3	21.1	11.4	7.2	2.3	1.6	11.3
Energy:														
Losses:														
Windows	GJ	-3.2	-2.5	-2.6	-1.8	-1.2	-0.8	-0.8	-0.8	-0.9	-1.4	-1.8	-2.8	-20.8
Other above grade	GJ	-4.1	-3.2	-3.3	-2.3	-1.3	-0.9	-0.9	-0.9	-1.0	-1.8	-2.3	-3.6	-25.6
to ground	GJ	-2.6	-2.4	-2.7	-1.9	-1.3	-1.9	-1.9	-1.9	-1.4	-2.0	-2.5	-2.6	-25.2
Infiltration	GJ	-3.4	-2.6	-2.4	-1.5	-0.8	-0.5	-0.5	-0.5	-0.5	-1.0	-1.4	-2.6	-17.7
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.3	-0.1	0.0	0.0	0.0	-0.9
Total	GJ	-13.4	-10.7	-11.0	-7.5	-4.6	-4.2	-4.4	-4.4	-4.0	-6.2	-8.0	-11.7	-90.1
Heating:														
Solar Gains	GJ	3.2	2.5	4.7	4.0	2.4	2.5	2.4	2.4	2.0	3.9	2.4	2.6	34.9
Internal Gains	GJ	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	22.8
Space heating	GJ	8.2	6.4	4.4	1.6	0.3	0.0	0.0	0.0	0.1	0.4	3.6	7.2	32.2
Total	GJ	13.4	10.7	11.0	7.5	4.6	4.4	4.3	4.4	3.9	6.2	7.9	11.7	89.9
Net Window gain	GJ	0.0	0.0	2.0	2.1						2.5	0.6	-0.3	6.9
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.3	-0.1	0.0	0.0	0.0	-0.9
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-1.0	-1.0	-0.9	-1.1	-1.2	0.0	0.0	0.0	-5.2

Temperatures		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>						
2nd floor	avg.	20.2	20.3	20.7	21.3	22.4	25.7	27.0	26.5	24.0	22.4	21.0	20.5	20.9
Main floor	avg.	20.4	20.5	20.9	21.4	22.5	25.8	27.1	26.6	24.1	22.6	21.2	20.6	21.1
Basement	avg.	20.3	20.4	20.5	20.9	22.0	24.9	26.3	25.8	23.6	22.0	20.8	20.4	20.7
Average		20.3	20.4	20.7	21.2	22.3	25.5	26.8	26.3	23.9	22.3	21.0	20.5	20.9
2nd floor	min	18.0	18.0	18.0	18.0	19.5	21.8	24.0	23.3	20.3	18.5	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.5	19.9	22.0	24.3	23.4	20.5	19.0	18.4	18.0	18.0
Basement	min	18.0	18.0	18.2	18.8	20.0	21.9	24.3	23.2	20.5	19.3	18.7	18.0	18.0
2nd floor	max	22.3	23.1	24.4	24.2	26.5	30.4	30.3	29.7	27.4	26.3	24.8	24.3	26.3
Main floor	max	22.1	22.9	24.1	24.3	26.6	30.4	30.1	29.8	27.5	26.1	24.6	24.0	26.1
Basement	max	21.2	21.5	22.2	22.5	25.0	28.5	28.5	28.0	26.0	24.4	23.3	22.6	24.4

Temperataure >25C:						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>						
2nd floor	hrs	0	0	0	0	35	490	708	608	234	31	0	0	31
	%	0%	0%	0%	0%	5%	68%	95%	82%	33%	4%	0%	0%	1%
Main floor	hrs	0	0	0	0	39	493	724	628	252	33	0	0	33
	%	0%	0%	0%	0%	5%	68%	97%	84%	35%	4%	0%	0%	1%
Basement	hrs	0	0	0	0	0	329	659	536	61	0	0	0	0
	%	0%	0%	0%	0%	0%	46%	89%	72%	8%	0%	0%	0%	0%

Notes:

APPENDIX B.2

Passive Solar Direct Gain House

ID: EDA05L08
1.2m overhangs

Suncode TMY predicted
Edmonton, Alberta
Forced air heat distribution
16.1 kW max. demand
Vent.: FA + HRV <60L/s
Total ac/h: 0.29 (Oct)
No air conditioning

Heated Floor Area 215.8 m2
Volume 548.3 m3
Heat Loss 151 W/C
0.7 W/m2 floor.C
Mass 17.7 MJ/C total (incl. 25mm conc.)
82 kJ/m2 floor.C
1.6 MJ/m2 S.glass C

Internal Gains 12.9 kWh/d
Temperature setpoints 21.0 C (day), 18.0 C (night)
venting 25.0 C (windows opened - summer only)

Glazing:	**South -**	**South -**	**East -**	**West -**	**North -**	**Total**	**Cavity loss**
2nd floor	3.3 m2	4.9% of floor area	2.2 m2	0.9 m2	1.7 m2	8.1 m2	6%
Main floor	3.8 m2	5.1% of floor area	2.7 m2	0.0 m2	1.2 m2	7.7 m2	7%
Basement	3.6 m2	4.9% of floor area	0.8 m2	0.0 m2	0.0 m2	4.5 m2	7%
TOTAL	10.7 m2	5.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	20.3 m2	
						9.4% of total floor area	

Glazing: ER = 2.7 SHGC = 0.37 RSI = 0.94
summer shading with curtains; no skyline shading
Ground albedo 0.50 winter (0.2 summer)

Ambient		Jan	Feb	Mar	Apr	<<<< May	Jun	summer Jul	Aug	Sep >>>>	Oct	Nov	Dec	Annual
Outside temp.	C	-17.8	-14.6	-8.2	5.6	10.2	14.2	15.2	15.2	10.0	1.1	-2.8	-8.0	1.7
Ground temp.	C	-0.6	0.2	2.2	5.3	8.3	10.7	11.6	10.9	8.7	5.7	2.5	0.3	5.5
Horiz. Insolation	MJ/m2d	4.3	7.6	13.0	16.2	20.6	24.0	21.9	20.9	11.3	8.7	4.4	3.0	13.0
Energy:														
Losses:														
Windows	GJ	-2.1	-1.7	-1.6	-0.8	-0.6	-0.5	-0.5	-0.5	-0.6	-1.1	-1.2	-1.6	-12.8
Other above grade	GJ	-5.3	-4.4	-3.9	-2.1	-1.5	-1.1	-1.1	-1.1	-1.5	-2.8	.-3.1	-3.9	-31.8
to ground	GJ	-2.2	-2.0	-2.2	-1.8	-1.3	-1.5	-1.6	-1.5	-1.2	-1.8	-2.1	-2.2	-21.4
Infiltration	GJ	-4.5	-3.4	-2.8	-1.3	-0.9	-0.6	-0.6	-0.6	-0.8	-1.7	-2.1	-2.8	-22.0
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.2
Total	GJ	-14.0	-11.5	-10.5	-6.0	-4.3	-3.8	-3.8	-3.7	-4.1	-7.4	-8.6	-10.4	-88.2
Heating:														
Solar Gains	GJ	2.7	3.0	3.9	3.3	2.3	2.5	2.4	2.3	1.4	3.6	2.3	2.0	31.6
Internal Gains	GJ	1.4	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.3	1.4	16.3
Space heating	GJ	10.0	7.3	5.3	1.4	0.6	0.0	0.0	0.0	1.3	2.4	5.0	7.0	40.2
Total	GJ	14.0	11.5	10.5	6.1	4.3	3.8	3.8	3.7	4.0	7.4	8.6	10.4	88.1
Net Window gain	GJ	0.6	1.2	2.3	2.5						2.5	1.0	0.5	10.6
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.2
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-0.7	-0.7	-0.7	-0.7	-0.7	0.0	0.0	0.0	-3.5

Temperatures		Jan	Feb	Mar	Apr	<<<< May	Jun	summer Jul	Aug	Sep >>>>	Oct	Nov	Dec	Heating Season
2nd floor	avg.	20.0	20.1	20.3	21.6	21.8	23.8	24.0	24.1	21.3	21.4	20.3	20.1	20.5
Main floor	avg.	20.1	20.2	20.5	21.7	21.9	23.9	24.1	24.2	21.4	21.6	20.4	20.2	20.7
Basement	avg.	20.1	20.1	20.2	21.1	21.4	23.2	23.4	23.6	21.1	21.2	20.3	20.2	20.5
Average		20.1	20.1	20.3	21.5	21.7	23.6	23.8	24.0	21.3	21.4	20.4	20.1	20.6
2nd floor	min	18.0	18.0	18.0	18.0	18.0	19.3	19.9	19.4	18.0	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.0	18.2	19.7	20.1	19.7	18.0	18.0	18.0	18.0	18.0
Basement	min	18.0	18.0	18.0	18.4	19.0	20.1	20.3	20.2	18.8	18.3	18.0	18.0	18.0
2nd floor	max	22.9	23.7	23.7	26.2	26.3	27.8	28.3	27.6	25.7	28.0	25.3	23.5	28.0
Main floor	max	22.9	23.7	23.6	25.9	26.4	27.9	28.4	27.7	25.7	27.6	25.0	23.5	27.6
Basement	max	21.4	21.9	21.7	23.8	24.6	26.0	26.3	25.9	23.9	25.2	22.7	21.8	25.2

Temperataure >25C:		Jan	Feb	Mar	Apr	<<<< May	Jun	summer Jul	Aug	Sep >>>>	Oct	Nov	Dec	
2nd floor	hrs	0	0	0	35	28	182	221	257	18	68	2	0	105
	%	0%	0%	0%	5%	4%	25%	30%	35%	3%	9%	0%	0%	2%
Main floor	hrs	0	0	0	33	27	177	234	262	14	70	0	0	103
	%	0%	0%	0%	5%	4%	25%	31%	35%	2%	9%	0%	0%	2%
Basement	hrs	0	0	0	0	0	46	43	104	0	3	0	0	3
	%	0%	0%	0%	0%	0%	6%	6%	14%	0%	0%	0%	0%	0%

Notes: Overheating in April (marginal) and October - low mass, low internals, 1.2m overhangs

APPENDIX B.2

Passive Solar Direct Gain House

ID: EDA05M08
1.2m overhangs

Heated Floor Area	215.8 m2
Volume	548.3 m3
Heat Loss	151 W/C
	0.7 W/m2 floor.C
Mass	24.9 MJ/C total (incl. 25mm conc.)
	115 kJ/m2 floor.C
	2.3 MJ/m2 S.glass C

Internal Gains	12.9 kWh/d	
Temperature setpoints	21.0 C (day),	18.0 C (night)
venting	25.0 C (windows opened - summer only)	

Suncode TMY predicted
Edmonton, Alberta
Forced air heat distribution
17.7 kW max. demand
Vent.: FA + HRV <60L/s
Total ac/h: 0.29 (Oct)
No air conditioning

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	3.3 m2	4.9% of floor area	2.2 m2	0.9 m2	1.7 m2	8.1 m2	6%
Main floor	3.8 m2	5.1% of floor area	2.7 m2	0.0 m2	1.2 m2	7.7 m2	7%
Basement	3.6 m2	4.9% of floor area	0.8 m2	0.0 m2	0.0 m2	4.5 m2	7%
TOTAL	10.7 m2	5.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	20.3 m2	
						9.4% of total floor area	

Glazing: ER = 2.7 SHGC = 0.37 RSI = 0.94
summer shading with curtains; no skyline shading

Ground albedo 0.50 winter (0.2 summer)

Ambient

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
Outside temp.	C	-17.8	-14.6	-8.2	5.6	10.2	14.2	15.2	15.2	10.0	1.1	-2.8	-8.0	1.7
Ground temp.	C	-0.6	0.2	2.2	5.3	8.3	10.7	11.6	10.9	8.7	5.7	2.5	0.3	5.5
Horiz. Insolation	MJ/m2d	4.3	7.6	13.0	16.2	20.6	24.0	21.9	20.9	11.3	8.7	4.4	3.0	13.0
Energy:														
Losses:														
Windows	GJ	-2.1	-1.7	-1.6	-0.8	-0.6	-0.5	-0.5	-0.5	-0.6	-1.1	-1.2	-1.6	-12.8
Other above grade	GJ	-5.2	-4.3	-3.9	-2.0	-1.5	-1.1	-1.1	-1.1	-1.4	-2.7	-3.1	-3.9	-31.3
to ground	GJ	-2.2	-2.0	-2.2	-1.8	-1.3	-1.5	-1.6	-1.5	-1.2	-1.8	-2.1	-2.2	-21.4
Infiltration	GJ	-4.5	-3.4	-2.8	-1.3	-0.9	-0.6	-0.6	-0.6	-0.8	-1.7	-2.1	-2.8	-22.1
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1
Total	GJ	-14.0	-11.4	-10.5	-6.0	-4.3	-3.8	-3.8	-3.7	-4.1	-7.4	-8.6	-10.4	-87.8
Heating:														
Solar Gains	GJ	2.7	3.0	3.9	3.3	2.3	2.5	2.4	2.3	1.4	3.6	2.3	2.0	31.6
Internal Gains	GJ	1.4	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.3	1.4	16.3
Space heating	GJ	9.9	7.2	5.2	1.3	0.5	0.0	0.0	0.0	1.3	2.3	4.9	7.0	39.7
Total	GJ	14.0	11.4	10.5	6.0	4.2	3.8	3.8	3.7	4.0	7.3	8.5	10.4	87.7
Net Window gain	GJ	0.6	1.2	2.3	2.5						2.5	1.0	0.5	10.6
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-0.7	-0.7	-0.7	-0.7	-0.7	0.0	0.0	0.0	-3.5

Temperatures

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	avg.	20.0	20.1	20.3	21.5	21.8	23.8	24.0	24.2	21.3	21.3	20.4	20.1	20.5
Main floor	avg.	20.1	20.2	20.5	21.6	21.9	23.9	24.1	24.3	21.5	21.5	20.5	20.2	20.7
Basement	avg.	20.1	20.2	20.3	21.1	21.4	23.2	23.4	23.7	21.1	21.1	20.4	20.3	20.5
Average		20.1	20.1	20.3	21.4	21.7	23.7	23.8	24.0	21.3	21.3	20.4	20.2	20.6
2nd floor	min	18.0	18.0	18.0	18.0	18.6	20.1	20.4	20.1	18.1	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.0	19.0	20.4	20.6	20.4	18.5	18.0	18.0	18.0	18.0
Basement	min	18.0	18.0	18.0	18.5	19.5	20.4	20.7	20.5	19.2	18.5	18.0	18.0	18.0
2nd floor	max	22.3	22.8	22.8	24.9	25.6	27.1	27.6	27.1	24.9	26.1	24.0	22.7	26.1
Main floor	max	22.4	22.9	22.8	24.9	25.7	27.3	27.7	27.2	25.0	26.1	23.9	22.8	26.1
Basement	max	21.2	21.5	21.4	23.1	24.2	25.7	25.9	25.6	23.4	24.2	22.2	21.5	24.2

Temperataure >25C:

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	hrs	0	0	0	0	14	140	199	240	0	25	0	0	25
	%	0%	0%	0%	0%	2%	19%	27%	32%	0%	3%	0%	0%	0%
Main floor	hrs	0	0	0	0	10	140	202	254	0	29	0	0	29
	%	0%	0%	0%	0%	1%	19%	27%	34%	0%	4%	0%	0%	1%
Basement	hrs	0	0	0	0	0	31	27	74	0	0	0	0	0
	%	0%	0%	0%	0%	0%	4%	4%	10%	0%	0%	0%	0%	0%

Notes: Acceptable overheating (October only - 2 zones) - mid mass, low internals, 1.2m overhangs

APPENDIX B.2

Passive Solar Direct Gain House

ID: EDA05H06
0.6m overhangs

Suncode TMY predicted
Edmonton, Alberta
Forced air heat distribution
21.7 kW max. demand
Vent.: FA + HRV <60L/s
Total ac/h: 0.29 (Oct)
No air conditioning

Heated Floor Area 215.8 m2
Volume 548.3 m3
Heat Loss 155 W/C
0.7 W/m2 floor.C
Mass 38.3 MJ/C total (incl. 25mm conc.)
177 kJ/m2 floor.C
3.6 MJ/m2 S.glass C

Internal Gains 12.9 kWh/d
Temperature setpoints 21.0 C (day), 18.0 C (night)
venting 25.0 C (windows opened - summer only)

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	3.3 m2	4.9% of floor area	2.2 m2	0.9 m2	1.7 m2	8.1 m2	4%
Main floor	3.8 m2	5.1% of floor area	2.7 m2	0.0 m2	1.2 m2	7.7 m2	5%
Basement	3.6 m2	4.9% of floor area	0.8 m2	0.0 m2	0.0 m2	4.5 m2	5%
TOTAL	10.7 m2	5.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	20.3 m2	
						9.4% of total floor area	

Glazing: ER = 2.7 SHGC = 0.37 RSI = 0.94
summer shading with curtains; no skyline shading
Ground albedo 0.50 winter (0.2 summer)

Ambient		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
Outside temp.	C	-17.8	-14.6	-8.2	5.6	10.2	14.2	15.2	15.2	10.0	1.1	-2.8	-8.0	1.7
Ground temp.	C	-0.6	0.2	2.2	5.3	8.3	10.7	11.6	10.9	8.7	5.7	2.5	0.3	5.5
Horiz. Insolation	MJ/m2d	4.3	7.6	13.0	16.2	20.6	24.0	21.9	20.9	11.3	8.7	4.4	3.0	13.0
Energy:														
Losses:														
Windows	GJ	-2.1	-1.7	-1.6	-0.9	-0.6	-0.5	-0.5	-0.5	-0.6	-1.1	-1.2	-1.6	-13.1
Other above grade	GJ	-5.2	-4.3	-3.9	-2.1	-1.5	-1.2	-1.1	-1.2	-1.5	-2.8	-3.1	-3.9	-31.6
to ground	GJ	-2.2	-2.0	-2.3	-1.9	-1.3	-1.6	-1.6	-1.6	-1.2	-1.8	-2.2	-2.2	-21.8
Infiltration	GJ	-4.5	-3.4	-2.9	-1.4	-0.9	-0.7	-0.6	-0.7	-0.8	-1.8	-2.1	-2.8	-22.5
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	0.0	0.0	0.0	0.0	-0.3
Total	GJ	-14.0	-11.5	-10.6	-6.3	-4.3	-3.9	-3.9	-4.1	-4.1	-7.5	-8.6	-10.5	-89.3
Heating:														
Solar Gains	GJ	2.8	3.3	4.6	4.0	2.5	2.6	2.6	2.6	1.6	4.3	2.4	2.1	35.4
Internal Gains	GJ	1.4	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.3	1.4	16.3
Space heating	GJ	9.8	6.9	4.6	0.9	0.3	0.0	0.0	0.0	1.1	1.9	4.9	7.0	37.3
Total	GJ	14.0	11.5	10.6	6.3	4.3	4.0	4.0	4.0	4.1	7.5	8.6	10.4	89.1
Net Window gain	GJ	0.7	1.5	3.0	3.2						3.1	1.1	0.5	13.1
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	0.0	0.0	0.0	0.0	-0.3
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-1.0	-0.9	-0.9	-1.2	-1.0	0.0	0.0	0.0	-5.0

Temperatures		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	avg.	20.2	20.2	20.6	22.2	21.9	24.1	24.3	25.0	21.6	21.7	20.5	20.3	20.8
Main floor	avg.	20.3	20.4	20.8	22.4	22.1	24.2	24.4	25.1	21.8	21.9	20.7	20.4	21.0
Basement	avg.	20.3	20.3	20.5	21.8	21.6	23.5	23.7	24.4	21.4	21.5	20.5	20.4	20.8
Average		20.2	20.3	20.6	22.1	21.9	23.9	24.2	24.8	21.6	21.7	20.6	20.4	20.9
2nd floor	min	18.0	18.0	18.0	18.3	19.4	20.7	21.2	21.5	18.9	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.9	19.8	21.0	21.4	21.8	19.4	18.5	18.0	18.0	18.0
Basement	min	18.0	18.1	18.2	19.1	19.9	20.8	21.2	21.7	19.7	18.9	18.1	18.1	18.0
2nd floor	max	22.0	22.6	23.0	25.7	25.3	26.9	27.4	27.2	25.2	26.8	23.3	22.1	26.8
Main floor	max	21.9	22.4	22.9	25.6	25.3	26.9	27.4	27.3	25.1	26.7	23.1	22.1	26.7
Basement	max	21.1	21.5	21.7	24.1	24.0	25.6	25.9	25.9	23.8	25.3	21.9	21.3	25.3

Temperataure >25C:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	hrs	0	0	0	27	9	149	230	398	8	34	0	0	61
	%	0%	0%	0%	4%	1%	21%	31%	53%	1%	5%	0%	0%	1%
Main floor	hrs	0	0	0	22	5	135	238	421	5	37	0	0	59
	%	0%	0%	0%	3%	1%	19%	32%	57%	1%	5%	0%	0%	1%
Basement	hrs	0	0	0	0	0	31	71	222	0	5	0	0	5
	%	0%	0%	0%	0%	0%	4%	10%	30%	0%	1%	0%	0%	0%

Notes: Overheating at close to acceptable levels (all zones) April & October

APPENDIX B.2

Passive Solar Direct Gain House

ID: VDN06L10

0.6m overhangs

Suncode TMY predicted
Vancouver, B.C.
Forced air heat distribution
17.1 kW max. demand
Vent.: none
Total ac/h: 0.27 (Oct)
No air conditioning

Heated Floor Area	215.8 m2	Internal Gains	17.4 kWh/d
Volume	548.3 m3	Temperature setpoints	21.0 C (day), 18.0 C (night)
Heat Loss	326 W/C	venting	25.0 C (windows opened - summer only)
	1.5 W/m2 floor.C		
Mass	17.6 MJ/C total (incl. 25mm conc.)		
	82 kJ/m2 floor.C		
	1.4 MJ/m2 S.glass C		

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	4.3 m2	6.3% of floor area	2.2 m2	0.9 m2	1.7 m2	9.1 m2	8%
Main floor	4.4 m2	6.0% of floor area	2.7 m2	0.0 m2	1.2 m2	8.3 m2	8%
Basement	4.2 m2	5.7% of floor area	0.8 m2	0.0 m2	0.0 m2	5.1 m2	7%
TOTAL	12.9 m2	6.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	22.5 m2	
						10.4% of total floor area	

Glazing: ER = -23.2 SHGC = 0.58 RSI = 0.39

summer shading with curtains; no skyline shading

Ground albedo 0.30 winter (0.2 summer)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
Ambient														
Outside temp.	C	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6	9.1
Ground temp.	C	6.8	7.4	8.9	11.1	13.4	15.1	15.8	15.3	13.6	11.4	9.1	7.5	11.3
Horiz. Insolation	MJ/m2d	2.3	4.8	8.3	13.7	19.8	18.4	24.3	21.1	11.4	7.2	2.3	1.6	11.3
Energy:														
Losses:														
Windows	GJ	-3.2	-2.4	-2.2	-2.1	-1.4	-1.1	-1.0	-0.9	-1.3	-2.0	-2.2	-3.2	-23.1
Other above grade	GJ	-4.9	-3.7	-3.3	-3.1	-2.0	-1.5	-1.3	-1.2	-1.8	-3.0	-3.4	-4.9	-34.1
to ground	GJ	-3.4	-3.1	-3.4	-2.5	-1.8	-1.7	-2.2	-2.3	-1.6	-2.6	-3.3	-3.4	-31.4
Infiltration	GJ	-3.3	-2.2	-2.0	-2.0	-1.1	-0.8	-0.7	-0.6	-0.9	-1.6	-1.9	-3.1	-20.3
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Total	GJ	-14.8	-11.4	-11.0	-9.8	-6.3	-5.2	-5.3	-5.1	-5.6	-9.1	-10.8	-14.6	-108.9
Heating:														
Solar Gains	GJ	1.9	2.3	2.8	3.5	2.7	2.5	3.1	3.0	2.1	3.7	1.4	1.6	30.5
Internal Gains	GJ	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	22.8
Space heating	GJ	10.9	7.3	6.3	4.4	1.7	0.8	0.3	0.1	1.6	3.5	7.5	11.1	55.4
Total	GJ	14.8	11.4	11.0	9.8	6.3	5.1	5.3	5.0	5.5	9.1	10.8	14.6	108.7
Net Window gain	GJ	-1.3	-0.1	0.5	1.4						1.7	-0.8	-1.6	-0.2
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-1.2	-1.1	-1.1	-1.5	-1.5	0.0	0.0	0.0	-6.5

Temperatures		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	avg.	20.0	20.2	20.3	20.5	21.2	21.6	23.1	23.7	21.1	21.0	20.1	20.0	20.3
Main floor	avg.	20.0	20.2	20.4	20.6	21.3	21.7	23.2	23.7	21.2	21.1	20.2	20.0	20.4
Basement	avg.	20.0	20.1	20.1	20.3	20.8	21.1	22.3	22.8	20.8	20.7	20.1	20.0	20.2
Average		20.0	20.1	20.3	20.4	21.1	21.5	22.9	23.4	21.0	20.9	20.1	20.0	20.3
2nd floor	min	18.0	18.0	18.0	18.0	18.0	18.2	18.4	19.6	18.0	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.0	18.0	18.4	18.6	19.6	18.0	18.0	18.0	18.0	18.0
Basement	min	18.0	18.0	18.0	18.0	18.3	19.1	19.2	19.8	18.6	18.1	18.0	18.0	18.0
2nd floor	max	23.9	24.9	25.1	24.9	25.3	25.2	28.4	28.0	24.8	27.8	24.7	23.2	27.8
Main floor	max	23.8	24.6	24.7	24.5	25.4	25.3	28.4	27.9	24.6	27.0	24.4	23.2	27.0
Basement	max	21.7	22.1	22.1	22.2	23.2	22.9	25.8	25.5	22.8	24.2	22.1	21.3	24.2

Temperataure >25C:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer	>>>>>>>>>>>>>>>>>>>>							
2nd floor	hrs	0	0	2	0	11	4	139	214	0	48	0	0	50
	%	0%	0%	0%	0%	1%	1%	19%	29%	0%	6%	0%	0%	1%
Main floor	hrs	0	0	0	0	7	5	129	205	0	45	0	0	45
	%	0%	0%	0%	0%	1%	1%	17%	28%	0%	6%	0%	0%	1%
Basement	hrs	0	0	0	0	0	0	14	19	0	0	0	0	0
	%	0%	0%	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%	0%

Notes: Overheating on main and 2nd floor somewhat excessive - reduce glazed area slightly
Overheating in October increased 3% to 4% (2nd & main floors, respectively) compared to 5% S. glazing (Cf VDN05L10)

APPENDIX B.2

Passive Solar Direct Gain House

ID: VDN06L13

0.6m overhangs

Suncode TMY predicted
Vancouver, B.C.
Forced air heat distribution
16.5 kW max. demand
Vent.: none
Total ac/h: 0.27 (Oct)
No air conditioning

Heated Floor Area	215.8 m2	
Volume	548.3 m3	
Heat Loss	312 W/C	
	1.4 W/m2 floor.C	
Mass	17.6 MJ/C total (incl. 25mm conc.)	
	82 kJ/m2 floor.C	
	1.4 MJ/m2 S.glass C	
Internal Gains	17.4 kWh/d	
Temperature setpoints	21.0 C (day),	18.0 C (night)
venting	25.0 C (windows opened - summer only)	

Glazing:	South -	South -	East -	West -	North -	Total	Cavity loss
2nd floor	4.3 m2	6.3% of floor area	2.2 m2	0.9 m2	1.7 m2	9.1 m2	8%
Main floor	4.4 m2	6.0% of floor area	2.7 m2	0.0 m2	1.2 m2	8.4 m2	8%
Basement	4.2 m2	5.7% of floor area	0.8 m2	0.0 m2	0.0 m2	5.1 m2	7%
TOTAL	12.9 m2	6.0% of total floor area	5.7 m2	0.9 m2	3.0 m2	22.5 m2	
						10.4% of total floor area	

Glazing: ER = -12.3 SHGC = 0.52 RSI = 0.52

summer shading with curtains; no skyline shading

Ground albedo 0.30 winter (0.2 summer)

Ambient		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>>						
Outside temp.	C	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6	9.1
Ground temp.	C	6.8	7.4	8.9	11.1	13.4	15.1	15.8	15.3	13.6	11.4	9.1	7.5	11.3
Horiz. Insolation	MJ/m2d	2.3	4.8	8.3	13.7	19.8	18.4	24.3	21.1	11.4	7.2	2.3	1.6	11.3
Energy:			Tg =		11.14	14.64 (summer)					11.43	7.92 (winter)		
Losses:														
Windows	GJ	-2.2	-1.6	-1.5	-1.5	-1.0	-0.8	-0.7	-0.6	-0.9	-1.3	-1.5	-2.2	-15.7
Other above grade	GJ	-4.9	-3.7	-3.3	-3.1	-2.0	-1.5	-1.3	-1.2	-1.8	-3.0	-3.4	-4.9	-34.1
to ground	GJ	-3.4	-3.1	-3.4	-2.5	-1.8	-1.8	-2.2	-2.3	-1.6	-2.6	-3.3	-3.4	-31.4
Infiltration	GJ	-3.3	-2.2	-2.0	-2.0	-1.1	-0.8	-0.7	-0.6	-0.9	-1.6	-1.9	-3.1	-20.3
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Total	GJ	-13.8	-10.6	-10.3	-9.1	-5.9	-4.8	-5.0	-4.8	-5.2	-8.5	-10.1	-13.6	-101.6
Heating:														
Solar Gains	GJ	1.8	2.1	2.5	3.2	2.4	2.3	2.8	2.7	1.9	3.3	1.3	1.4	27.7
Internal Gains	GJ	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	22.8
Space heating	GJ	10.1	6.8	5.9	4.1	1.5	0.7	0.2	0.1	1.4	3.2	6.9	10.2	51.0
Total	GJ	13.7	10.6	10.3	9.1	5.9	4.8	5.0	4.7	5.2	8.5	10.1	13.6	101.5
Net Window gain	GJ	-0.4	0.5	1.0	1.7						2.0	-0.2	-0.7	3.8
Cooling:														
Space venting	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Space cooling	GJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
User shaded	GJ	0.0	0.0	0.0	0.0	-1.1	-1.0	-1.0	-1.4	-1.4	0.0	0.0	0.0	-5.9

Temperatures		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Heating Season
						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>>						
2nd floor	avg.	20.0	20.2	20.3	20.5	21.2	21.7	23.2	23.7	21.1	21.0	20.1	20.0	20.3
Main floor	avg.	20.1	20.2	20.4	20.6	21.3	21.8	23.2	23.7	21.3	21.1	20.2	20.1	20.4
Basement	avg.	20.0	20.1	20.1	20.3	20.8	21.1	22.3	22.8	20.8	20.7	20.1	20.0	20.2
Average		20.0	20.2	20.3	20.5	21.1	21.5	22.9	23.4	21.1	20.9	20.2	20.0	20.3
2nd floor	min	18.0	18.0	18.0	18.0	18.0	18.5	18.6	19.7	18.0	18.0	18.0	18.0	18.0
Main floor	min	18.0	18.0	18.0	18.0	18.0	18.6	18.8	19.8	18.0	18.0	18.0	18.0	18.0
Basement	min	18.0	18.0	18.0	18.0	18.3	19.2	19.3	19.9	18.7	18.2	18.0	18.0	18.0
2nd floor	max	23.7	24.6	24.8	24.6	25.1	25.0	28.1	27.7	24.7	27.3	24.4	23.0	27.3
Main floor	max	23.6	24.3	24.4	24.2	25.3	25.2	28.2	27.7	24.6	26.7	24.1	23.0	26.7
Basement	max	21.6	21.9	22.0	22.1	23.2	22.9	25.5	25.3	22.8	23.9	21.9	21.2	23.9

Temperataure >25C:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
						<<<<<<<<<<<< summer		>>>>>>>>>>>>>>>>>>>>						
2nd floor	hrs	0	0	0	0	7	1	133	206	0	40	0	0	40
	%	0%	0%	0%	0%	1%	0%	18%	28%	0%	5%	0%	0%	1%
Main floor	hrs	0	0	0	0	6	3	118	195	0	35	0	0	35
	%	0%	0%	0%	0%	1%	0%	16%	26%	0%	5%	0%	0%	1%
Basement	hrs	0	0	0	0	0	0	13	15	0	0	0	0	0
	%	0%	0%	0%	0%	0%	0%	2%	2%	0%	0%	0%	0%	0%

Notes: Overheating on main and second floors close to acceptable levels
1% less overheating than with double glazing

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Vancouver CMHC Healthy House

INPUTS:

Note: make inputs only in boxed areas

1 **Location** | 11 | Vancouver BC
(see **Weather** sheet for list of cities)

House Description:

2 Detached/Attached?	D	D = detached, A = attached (duplex, row)
Main & Upper Floor Area	136.7	m^2
Basement heated?	N	(Y/N)
Basement Floor Area	0.0	m^2
Total heated floor area	136.7	m^2

3 South Windows:

Area -

main & upper floors	7.6	m^2 (SE to SW) (5.6% of floor area)
unheated basement	0.0	m^2 (SE to SW)
Total South windows	7.6	m^2 (SE to SW - in heated areas)
	5.6%	of heated floor area

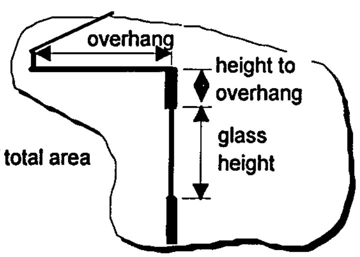
Type -

- # glazings	2	(predominant type)
- # low E coatings	1	
- shading by curtains	10	% obscured
October to April shading	20	% to the south; 10AM to 2PM

Shading -

Window - overhang	0.40	m
- height to overhang	0.30	m
- avg. glass height	1.00	m
South glass area with above overhang	60	% of total area

(rest assumed to have no overhang)



With inputs shown -
south window area is **89%** of recommended south glazed area

OUTPUTS:

Heating Degree Days	3,007 (below base 18C)
Cooling Degree Days	38 (above base 18C)
Latitude	49.3 °N.

Solar elevations for Vancouver:

noon, June 21	64 degrees (highest sun angle)
11AM, August 21	51 degrees (approx. 10AM - 2PM)
11AM, October 21	30 degrees (approx. 10AM - 2PM)
noon, December 21	17 degrees (lowest noon sun angle)

RECOMMENDATIONS

To avoid excessive overheating -

Max. S. Window Area 8.6 m^2 (SE to SW - in heated areas)
6.3% of heated floor area

For the house specified -

About 0% hrs. overheating (fall); S. window area could be increased, however glazing heat losses may exceed gains due to shading

Shading by curtains is typically about 10% to 15% (depending on usage)
Estimate on-site shading from horizontal up to 30 degrees and about 45 degrees each side of south

Window Location & Shading:

min. height to overhang 0.23 m to minimize shading Oct to Feb

Approx. glass shading
53% shaded in June at noon
19% shaded in August (10AM - 2PM)
0% shaded in October (10AM - 2PM)
(for windows with indicated overhang)

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Vancouver CMHC Healthy House

With inputs shown - south window area is **89%** of recommended south glazed area

4 East/West Windows:

East: Area -	3.2	m^2 (NE to SE - in heated areas)	While some East windows are desirable for morning warmup, reduce overheating with reduced area and/or external shading.
	2.3%	of heated floor area	
West: Area -	2.0	m^2 (SW to NW - in heated areas)	
	1.5%	of heated floor area	
Type & Shading -			
E/W - # glazings	2	(predominant type)	
- # low E coatings	1		
- tinting/shading	10	% obscured	
Fall/Spring external shading	0	% to the East, 8AM to 10AM	
	0	% to the West, 2PM to 4PM	Estimate East and West shading from horizontal up to about 30 degrees

5 Mass:

Extra mass?	2	1: none (wood frame const.) 2: double gyproc or floor topcoat 3: extensive brick/concrete	Thermal storage mass located in the sun is most effective

6 Insulation/Air Tightness:

Conservation level	2	1: standard new construction 2: R-2000 levels 3: Advanced house levels

7 Mechanical Systems:

Cooling system	1	1: none 2: air conditioning or heat pump	
Heating Distribution	1	1: forced air 2: baseboards, radiant floor/ceiling	Ensure that return air draws from high in solar heated areas
	70	% of thermal storage mass in south rooms	

8 Occupancy:

Appliance/lighting efficiency	2	1: conventional appl.; incandescent lights 2: medium efficiency appliances 3: high efficiency appliances; fluorescent lights	Assumed utiliities 17.4 kWh/day (inside house)
Thermostat setpoint	21.0	C (day-time)	A day/night temperature swing is necessary for effective use of thermal storage, however, day/night temperature swings in this house will typically be less than 3.0C.
	18.0	C (night-time)	

NOTES:

This Design Checker is based on correlations with hourly simulations. The Design checker produces results within 2% (of predicted hours of overheating) of the original correlations, 81% of the time - this amounts to a difference in recommended south glazed area of less than 0.5% of the heated floor area. It is intended to be used only in a heating dominant climate. The guidelines for south glazed area apply to the heating season only (assumed to be October to April). Overheating is considered to occur if the temperature exceeded the set-point temperature by more than 4C. Overheating is considered excessive if it exceeded 4% of the hours in a given month (based on occupant surveys). October was found to be the critical overheating month in virtually all cases.

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Edmonton R-2000 house

INPUTS:

Note: make inputs only in boxed areas

1 Location | 15 | Edmonton AB
(see **Weather** sheet for list of cities)

House Description:

2	Detached/Attached?	D	D = detached, A = attached (duplex, row)
	Main & Upper Floor Area	94.0	m^2
	Basement heated?	Y	(Y/N)
	Basement Floor Area	94.0	m^2
	Total heated floor area	188	m^2

3 South Windows:

Area -

main & upper floors	6.0	m^2 (SE to SW)	(6.4% of floor area)
heated basement	4.5	m^2 (SE to SW)	(4.8% of floor area)
Total South windows	10.5	m^2 (SE to SW - in heated areas)	
	5.6%	of heated floor area	

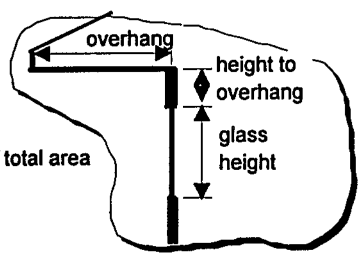
Type -

- # glazings	2	(predominant type)
- # low E coatings	1	
- shading by curtains	15	% obscured
October to April shading	0	% to the south; 10AM to 2PM

Shading -

Window - overhang	0.60	m
- height to overhang	0.20	m
- avg. glass height	1.10	m
South glass area with above overhang	60	% of total area

(rest assumed to have no overhang)



With inputs shown -
south window area is **131%** of recommended south glazed area

OUTPUTS:

Heating Degree Days	5,589 (below base 18C)
Cooling Degree Days	81 (above base 18C)
Latitude	53.6 °N.

Solar elevations for Edmonton:

noon, June 21	60 degrees (highest sun angle)
11AM, August 21	47 degrees (approx. 10AM - 2PM)
11AM, October 21	25 degrees (approx. 10AM - 2PM)
noon, December 21	13 degrees (lowest noon sun angle)

RECOMMENDATIONS

To avoid excessive overheating -

Max. S. Window Area 8.0 m^2 (SE to SW - in heated areas)
4.3% of heated floor area

For the house specified -

About 11% hrs. overheating (fall); Reduce south window area, shade and/or increase thermal storage mass inside the house
Overheating on main & upper floors likely
Overheating in basement likely

Internal shading reduces the solar collection effectiveness
Estimate on-site shading from horizontal up to 25 degrees and about 45 degrees each side of south

Window Location & Shading:

min. height to overhang 0.28 m to minimize shading Oct to Feb
with a height to overhang of 0.20m some winter shading will occur

Approx. glass shading
76% shaded in June at noon
40% shaded in August (10AM - 2PM)
8% shaded in October (10AM - 2PM)
(for windows with indicated overhang)

Increasing the window overhang will reduce overheating

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Edmonton R-2000 house

With inputs shown -
south window area is **131%** of recommended south glazed area

4 **East/West Windows:**

East: Area -	1.2	m^2 (NE to SE - in heated areas)	
	0.6%	of heated floor area	
West: Area -	0.0	m^2 (SW to NW - in heated areas)	
	0.0%	of heated floor area	
Type & Shading -			
E/W - # glazings	2	(predominant type)	
- # low E coatings	1		
- tinting/shading	10	% obscured	
Fall/Spring external shading	0	% to the East, 8AM to 10AM	
	100	% to the West, 2PM to 4PM	Estimate East and West shading from horizontal up to about 30 degrees

5 **Mass:**

Extra mass?	1	1: none (wood frame const.) 2: double gyproc or floor topcoat 3: extensive brick/concrete	Thermal storage mass located in the sun is most effective Increased mass will allow for increased glazing

6 **Insulation/Air Tightness:**

Conservation level	2	1: standard new construction 2: R-2000 levels 3: Advanced house levels

7 **Mechanical Systems:**

Cooling system	1	1: none 2: air conditioning or heat pump	Mechanical cooling may be required in the fall and/or spring - consider reducing window area/increasing overhang, and/or increasing mass
Heating Distribution	1	1: forced air 2: baseboards, radiant floor/ceiling	Ensure that return air draws from high in solar heated areas
	70	% of thermal storage mass in south rooms	

8 **Occupancy:**

Appliance/lighting efficiency	2	1: conventional appl.; incandescent lights 2: medium efficiency appliances 3: high efficiency appliances; fluorescent lights	Assumed utilities 17.4 kWh/day (inside house)
Thermostat setpoint	21.0	C (day-time)	A day/night temperature swing is necessary for effective use of thermal storage, however, day/night temperature swings in this house will typically be less than 3.0C.
	18.0	C (night-time)	

NOTES:

This Design Checker is based on correlations with hourly simulations. The Design checker produces results within 2% (of predicted hours of overheating) of the original correlations, 81% of the time - this amounts to a difference in recommended south glazed area of less than 0.5% of the heated floor area. It is intended to be used only in a heating dominant climate. The guidelines for south glazed area apply to the heating season only (assumed to be October to April). Overheating is considered to occur if the temperature exceeded the set-point temperature by more than 4C. Overheating is considered excessive if it exceeded 4% of the hours in a given month (based on occupant surveys). October was found to be the critical overheating month in virtually all cases.

APPENDIX C

HOUSE COMFORT DESIGN CHECKER

for WINTER SOLAR OVERHEATING

Ottawa Advanced House

INPUTS:

Note: make inputs only in boxed areas

1	**Location**	36	Ottawa ON (see **Weather** sheet for list of cities)

House Description:

2	Detached/Attached?	D	D = detached, A = attached (duplex, row)
	Main & Upper Floor Area	194.0	m^2
	Basement heated?	Y	(Y/N)
	Basement Floor Area	79.0	m^2
	Total heated floor area	273	m^2

3 South Windows:

Area -

main & upper floors	12.6	m^2 (SE to SW)	(6.5% of floor area)
heated basement	1.1	m^2 (SE to SW)	(1.4% of floor area)
Total South windows	13.7	m^2 (SE to SW - in heated areas)	
	5.0%	of heated floor area	

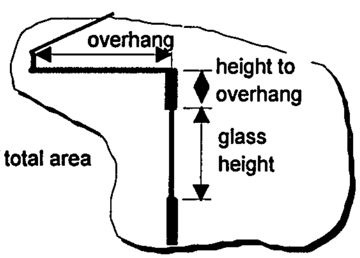
Type -

- # glazings	3	(predominant type)
- # low E coatings	1	
- shading by curtains	10	% obscured
October to April shading	10	% to the south; 10AM to 2PM

Shading -

Window - overhang	0.50	m
- height to overhang	0.20	m
- avg. glass height	1.00	m
South glass area with above overhang	60	% of total area

(rest assumed to have no overhang)



With inputs shown -
south window area is **103%** of recommended south glazed area

OUTPUTS:

Heating Degree Days	4,673 (below base 18C)
Cooling Degree Days	232 (above base 18C)
Latitude	45.5 °N.

Solar elevations for Ottawa:

noon, June 21	68 degrees (highest sun angle)
11AM, August 21	54 degrees (approx. 10AM - 2PM)
11AM, October 21	33 degrees (approx. 10AM - 2PM)
noon, December 21	21 degrees (lowest noon sun angle)

RECOMMENDATIONS

To avoid excessive overheating -

Max. S. Window Area 13.3 m^2 (SE to SW - in heated areas)
4.9% of heated floor area

For the house specified -

About 5% hrs. overheating (fall); Reduce south window area, shade and/or increase thermal storage mass inside the house

Overheating on main & upper floors likely, consider redistributing windows to basement

Shading by curtains is typically about 10% to 15% (depending on usage)

Estimate on-site shading from horizontal up to 33 degrees and about 45 degrees each side of south

Window Location & Shading:

min. height to overhang 0.33 m to minimize shading Oct to Feb
with a height to overhang of 0.20m significant winter shading will occur

Approx. glass shading	100% shaded in June at noon
	49% shaded in August (10AM - 2PM)
	13% shaded in October (10AM - 2PM)

(for windows with indicated overhang)

Increasing the window overhang will reduce overheating

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Ottawa Advanced House

With inputs shown -
south window area is **103%** of recommended south glazed area

4 East/West Windows:

East: Area - 0.9 m^2 (NE to SE - in heated areas)
0.3% of heated floor area

West: Area - 2.2 m^2 (SW to NW - in heated areas)
0.8% of heated floor area

Type & Shading -

E/W - # glazings	3	(predominant type)
- # low E coatings	1	
- tinting/shading	10	% obscured
Fall/Spring external shading	20	% to the East, 8AM to 10AM
	0	% to the West, 2PM to 4PM

Estimate East and West shading from horizontal up to about 30 degrees

5 Mass:

Extra mass? 1
1: none (wood frame const.)
2: double gyproc or floor topcoat
3: extensive brick/concrete

Thermal storage mass located in the sun is most effective
Increased mass will allow for increased glazing

6 Insulation/Air Tightness:

Conservation level 3
1: standard new construction
2: R-2000 levels
3: Advanced house levels

7 Mechanical Systems:

Cooling system 1
1: none
2: air conditioning or heat pump

Heating Distribution 1
1: forced air
2: baseboards, radiant floor/ceiling

70 % of thermal storage mass in south rooms

Mechanical cooling may be required in the fall and/or spring
- consider reducing window area/increasing overhang, and/or increasing mass
Ensure that return air draws from high in solar heated areas

8 Occupancy:

Appliance/lighting efficiency 3
1: conventional appl.; incandescent lights
2: medium efficiency appliances
3: high efficiency appliances; fluorescent lights

Assumed utilities 12.9 kWh/day (inside house)

Thermostat setpoint
21.0 C (day-time)
18.0 C (night-time)

A day/night temperature swing is necessary for effective use of thermal storage, however, day/night temperature swings in this house will typically be less than 3.0C.

NOTES:
This Design Checker is based on correlations with hourly simulations. The Design checker produces results within 2% (of predicted hours of overheating) of the original correlations, 81% of the time - this amounts to a difference in recommended south glazed area of less than 0.5% of the heated floor area. It is intended to be used only in a heating dominant climate. The guidelines for south glazed area apply to the heating season only (assumed to be October to April). Overheating is considered to occur if the temperature exceeded the set-point temperature by more than 4C. Overheating is considered excessive if it exceeded 4% of the hours in a given month (based on occupant surveys). October was found to be the critical overheating month in virtually all cases.

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Yarrow house

INPUTS:

Note: make inputs only in boxed areas

1 Location | 11 | Vancouver BC
(see **Weather** sheet for list of cities)

House Description:

2 Detached/Attached?	D	D = detached, A = attached (duplex, row)
Main & Upper Floor Area	205.0	m^2
Basement heated?	N	(Y/N)
Basement Floor Area	0.0	m^2
Total heated floor area	205	m^2

3 South Windows:

Area -

main & upper floors	19.0	m^2 (SE to SW) (9.3% of floor area)
unheated basement	0.0	m^2 (SE to SW)
Total South windows	19.0	m^2 (SE to SW - in heated areas)
	9.3%	of heated floor area

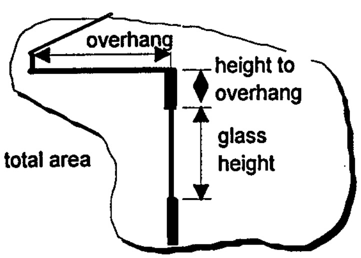
Type -

- # glazings	3	(predominant type)
- # low E coatings	0	
- shading by curtains	10	% obscured
October to April shading	15	% to the south; 10AM to 2PM

Shading -

Window - overhang	1.20	m
- height to overhang	0.30	m
- avg. glass height	1.20	m
South glass area with above overhang	60	% of total area

(rest assumed to have no overhang)



With inputs shown -
south window area is **105%** of recommended south glazed area

OUTPUTS:

Heating Degree Days	3,007	(below base 18C)
Cooling Degree Days	38	(above base 18C)
Latitude	49.3	°N.

Solar elevations for Vancouver:

noon, June 21	64	degrees (highest sun angle)
11AM, August 21	51	degrees (approx. 10AM - 2PM)
11AM, October 21	30	degrees (approx. 10AM - 2PM)
noon, December 21	17	degrees (lowest noon sun angle)

RECOMMENDATIONS

To avoid excessive overheating -

Max. S. Window Area 18.1 m^2 (SE to SW - in heated areas)
8.8% of heated floor area

For the house specified -

About 6% hrs. overheating (fall); Reduce south window area, shade and/or increase thermal storage mass inside the house
Overheating on main & upper floors possible

Shading by curtains is typically about 10% to 15% (depending on usage)
Estimate on-site shading from horizontal up to 30 degrees and about 45 degrees each side of south

Window Location & Shading:

min. height to overhang 0.68 m to minimize shading Oct to Feb
with a height to overhang of 0.30m significant winter shading will occur

Approx. glass shading 100% shaded in June at noon
98% shaded in August (10AM - 2PM)
32% shaded in October (10AM - 2PM)
(for windows with indicated overhang)

Increasing the window overhang will reduce overheating

APPENDIX C

HOUSE COMFORT DESIGN CHECKER
for WINTER SOLAR OVERHEATING

Yarrow house

With inputs shown -
south window area is **105%** of recommended south glazed area

4 East/West Windows:

East: Area - 0.0 m^2 (NE to SE - in heated areas)
0.0% of heated floor area

West: Area - 2.2 m^2 (SW to NW - in heated areas)
1.1% of heated floor area

Type & Shading -

E/W - # glazings	3	(predominant type)
- # low E coatings	0	
- tinting/shading	10	% obscured
Fall/Spring external shading	0	% to the East, 8AM to 10AM
	0	% to the West, 2PM to 4PM

Estimate East and West shading from horizontal up to about 30 degrees

5 Mass:

Extra mass? 2
1: none (wood frame const.)
2: double gyproc or floor topcoat
3: extensive brick/concrete

Thermal storage mass located in the sun is most effective
Increased mass will allow for increased glazing

6 Insulation/Air Tightness:

Conservation level 2
1: standard new construction
2: R-2000 levels
3: Advanced house levels

7 Mechanical Systems:

Cooling system 1
1: none
2: air conditioning or heat pump

Mechanical cooling may be required in the fall and/or spring
- consider reducing window area/increasing overhang, and/or increasing mass

Heating Distribution 1
1: forced air
2: baseboards, radiant floor/ceiling

Ensure that return air draws from high in solar heated areas

70 % of thermal storage mass in south rooms

8 Occupancy:

Appliance/lighting efficiency 2
1: conventional appl.; incandescent lights
2: medium efficiency appliances
3: high efficiency appliances; fluorescent lights

Assumed utiliities 17.4 kWh/day (inside house)

Thermostat setpoint
21.0 C (day-time)
18.0 C (night-time)

A day/night temperature swing is necessary for effective use of thermal storage, however, day/night temperature swings in this house will typically be less than 3.0C.

NOTES:

This Design Checker is based on correlations with hourly simulations. The Design checker produces results within 2% (of predicted hours of overheating) of the original correlations, 81% of the time - this amounts to a difference in recommended south glazed area of less than 0.5% of the heated floor area. It is intended to be used only in a heating dominant climate. The guidelines for south glazed area apply to the heating season only (assumed to be October to April). Overheating is considered to occur if the temperature exceeded the set-point temperature by more than 4C. Overheating is considered excessive if it exceeded 4% of the hours in a given month (based on occupant surveys). October was found to be the critical overheating month in virtually all cases.