

Second Generation Greenhomes for Northern Climates

by John W. Evans and Philip Pratt

This paper describes a second generation of "Greenhomes" that are being designed to meet the needs of the middle price housing market. Learning from the mistakes and successes of the "Newfoundland Greenhome", better energy efficiency and lower construction costs are expected.

A "Greenhome" is a type of energy efficient house especially designed for cold wet climates. The design sets out to avoid two problems which have become very common in Canadian housing during the past decade. Structural condensation and interior air pollution are the result of an incomplete understanding of the effects of adding insulation to houses. The "Greenhome" is designed 1) to be energy efficient, 2) to have adequate natural ventilation and 3) to avoid structural condensation. While a "Greenhome" accepts solar gain during the heating season its primary strength is its low energy requirements during long periods of overcast weather.

INTRODUCTION

The Newfoundland Greenhome was the first passive solar home to be built in Newfoundland. Design work began in the fall of 1978 and the house has been occupied by the senior author since June 1980. Papers describing the design and analysis of function have been published by Evans and Mellin (1, 2, 3). Design problems and microclimatic considerations have been described by Evans (4, 5).

The major accomplishment of the Newfoundland Greenhome was to create an exceedingly energy efficient design, while simultaneously providing adequate passive ventilation and avoiding structural condensation.

In this paper we will take the "Greenhome" idea another step forward by describing designs for second generation Greenhomes. These designs seek to take advantage of the successful innovative features of the Newfoundland Greenhome and to delete the unsuccessful traditional features.

Second generation Greenhomes are an attempt to create a functionally ideal house for cold damp northern climates. For the present, considerations of style, aesthetic beauty etc. will be laid aside so that we can focus upon the serious functional problems facing housing in these areas.

Inflexibility of design in severe climates

It is the authors' contention that if one wishes to have functionally correct houses there is progressively less design flexibility as one builds in increasingly harsh climates.

A biological analogy will help to introduce this idea. In easy subtropical and tropical climates biological diver-

sity is high. Plants and animals come in many different shapes, sizes and colours and successfully share similar habitats.

Similarly in easy climates, where resources are adequate, we see a great diversity of housing designs. Practically any structure with walls and a roof will work satisfactorily as a shelter. This gives the designer great flexibility, to explore a variety of aesthetically different and pleasing designs and experiment with a variety of building materials. In other words function can and often does follow form.

In harsh climates, like the Canadian Arctic and boreal regions, biological diversity is comparatively very low. (Boreal regions are recognized as those areas where the primary forest trees are conifers, like black spruce and balsam fir.) When you ignore the many species of birds that migrate north for the summer months, one finds that there are relatively few terrestrial species which are permanent residents. Because the environmental conditions are so harsh and uncompromising there is little room for design flexibility. If you are different you are dead.

In the arctic and boreal regions, form very definitely follows function. Every animal in the arctic has to take into account the reality of extreme cold. Dense heat retaining and water resistant fur, insulative plumage, fat layers, and hibernation are adaptations for surviving in extremely cold conditions.

Similarly with northern housing, the designer's primary responsibility must be to meet the functional challenges of the climate. Necessarily this is going to mean that there is a narrow range of design options open to him. Disregarding minor interior variations there can be few functionally correct designs for a given location in the north. Support for this contention is demonstrated by the general lack of success of house designs which are imported into the north from more southern regions.

GREENHOME CONCEPT

Functional requirements of northern housing

The functional requirements of an ideal northern house can be summarized as follows. It should be energy conserving, have adequate ventilation, avoid structural condensation, should suit the functional requirements of the occupants, should be buildable, affordable and relatively maintenance free. The Newfoundland Greenhome met most of these criteria quite well. It failed mostly in affordability and buildability. This was because it was unnecessarily architecturally complex and because it was experimental in nature, thus expensive errors were made (Evans 1981).

The Second Generation Greenhome design (referred to simply as Greenhome from now on) attempts to satisfy all of the functional criteria.

Greenhomes were originally designed to meet the functional demands of a cold wet windy climate such as is experienced in St. John's, Newfoundland. However we believe that the concept is also adaptable with minor modifications to far northern conditions.

Basic Design Theory

A greenhome is a superinsulated house that breathes preheated air from a wind free climate formed by a large attached sunspace on the east and south sides. Air is drawn into the house through purposely infiltratable walls. Controlled infiltration is induced by keeping the interior pressure slightly below that of the protective sunspace. This is accomplished by exhausting used interior air out through chimneys or stack vents. North and west walls are superinsulated, super air-tight and totally lacking in doors, windows or other openings. All doors and windows from the heated living area open into the sun space.

A Row House Greenhome for St. John's

The greenhome can assume a number of different configurations, depending on the density of construction and the size of the individual units. Units on large lots will be differently arranged than units on narrow lots and similarly a row house will again be different. In this presentation we will limit ourselves to a row house configuration as this seems to be the most acceptable form for moderate priced housing in the St. John's market.

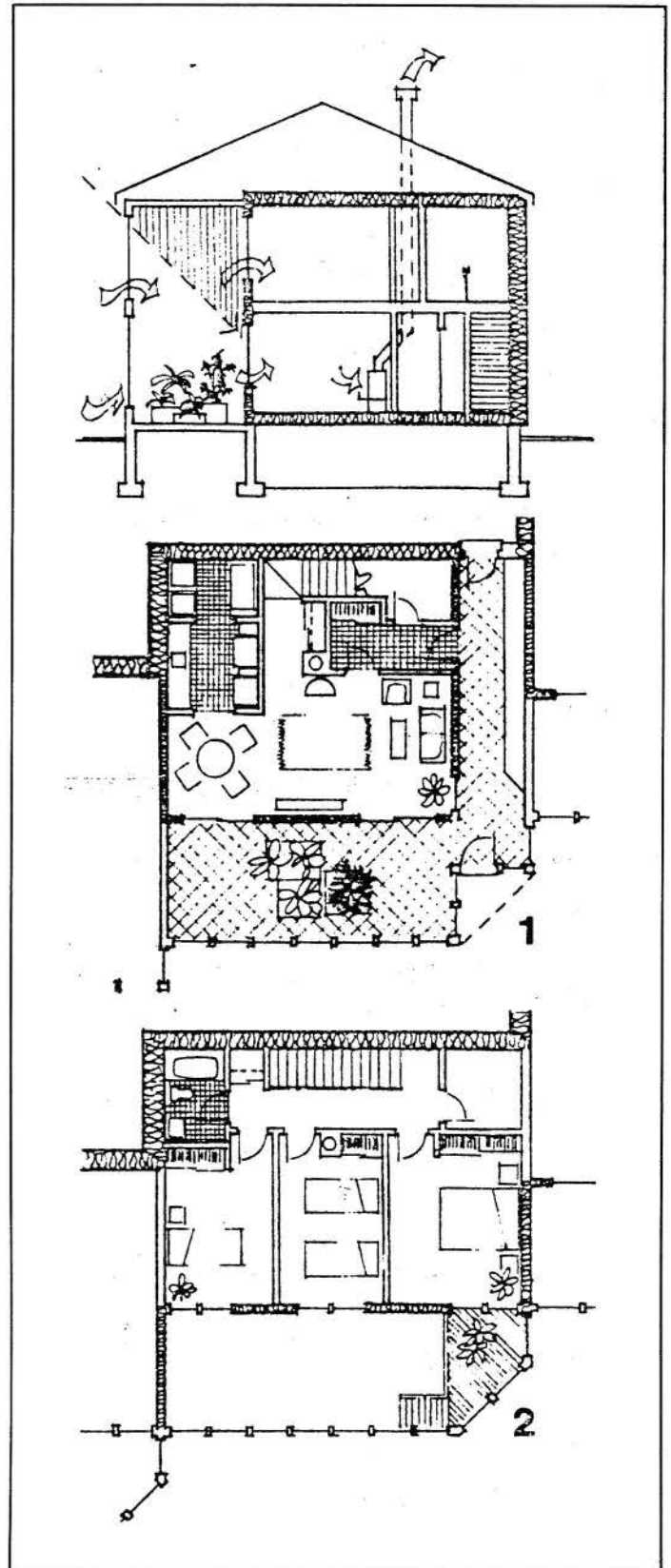
DESIGN GOALS AND GREENHOME PHYSIOLOGY

Heating

Heating energy costs should be under \$1.00/m²/year in the St. John's area. Recent surveys of St. John's housing showed heating costs to range from \$5.00 for newer houses to \$21.30/m²/year in some older houses. An average cost of \$11.30 m²/yr. was recorded.

In 1981-82 heating season 1 ¼ cords of low quality fire wood was used in the Newfoundland Greenhome and in 1982-83, ¾ of a cord was used. At \$60.00/cord heating costs work out to less than \$0.30/m²/year. With this background the goal of less than \$1.00/m²/year for the Greenhome seems very conservative.

This level of energy efficiency will be achieved in a number of ways. 1) South and east orientation of all windows encourages the passive collection of early morning and daytime solar energy. 2) Superinsulation of the upper ceiling, the lower floor, the north wall and the exposed portion of the west wall will reduce energy loss through these surfaces to an insignificant level. 3) The east and south walls will be protected by a sunspace. Thus a wind free, solar heated, microclimate will enclose these vulnerable walls. 4) All doors will open into the sunspace. 5) Pulsed ventilation (see below) reduces the ΔT of the infiltrating air, thereby minimizing the energy required to raise the ventilation air to room temperature.



Conceptual drawings for Greenhome row housing: section (top), ground level (middle), upper level (bottom).

6) All major electrical appliances will be located within the insulated living space so that intrinsic energy production will be maximized.

Air Quality

The maintenance of high quality air will be one of the primary design objectives for the Greenhome. Not only is this important for the health of the occupants but also for the structural health of the house.

In the Newfoundland Greenhome satisfactory ventilation has been maintained without the need for fans or air to air heat exchangers (3). This passive ventilation is due to the slightly negative pressure which is maintained within the living space by the sucking action of the three chimneys (one for a composting toilet and two for wood stoves, one upstairs and one downstairs).

When these chimneys draw the used air out of the house it is replaced by fresh air which infiltrates from the greenhouse through the leaky south wall. The energy needed to raise this fresh air to room temperature is minimal during the day, because the air is preheated within the greenhouse. For details about the greenhouse microclimate see Evans & Mellin (3) and Evans (5).

Pulsed ventilation

Rather than ventilating the Greenhome on a continuous basis it is recommended that ventilation be encouraged during the day and discouraged at night. This strategy of pulsed ventilation would optimize energy conservation and provide abundant fresh air when it is needed. During the day increased household activity produces more pollutants and requires more oxygen.

The Greenhome is adaptable to any sort of auxillary heating system. If the fuel is wood, oil or gas the heater should be located within the living space and should draw combustion air from within the house. This will help to create the desired negative pressure in the living space and will forcefully exhaust used air from the house. On no account should combustion air be drawn from outside as this would short circuit the ventilating system.

Ideally combustion should be restricted to daylight hours in order to take advantage of the elevated temperature of the infiltration air from the Greenhouse. This would reduce the importation of cold air during the night. Strategically located thermal mass placed around the fuel burner would help to reduce temperature fluctuations during non-burning periods.

In electrically heated greenhomes the heating and ventilation functions could be decoupled. Standard thermostatically controlled electric heat would keep the living space from falling below a minimum temperature. Stack vents would passively exhaust used air from the house and maintain the negative interior pressure. The rate of ventilation would be controlled by electrically operated dampers which would be light actuated, opening during the day and closing at night.

Relative Humidity and Structural Condensation

What is the optimum level of relative humidity within a house? The answer depends on whether you are designing for the health and comfort of the occupants or for the longevity and health of the house. The building trade promotes low interior relative humidities because it is easier to avoid structural condensation under those conditions. Occupants on the other hand have found that they tend to be more comfortable and healthier under conditions from 35% to 60% relative humidity (6).

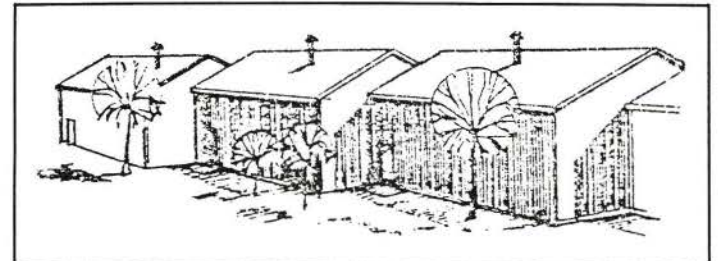
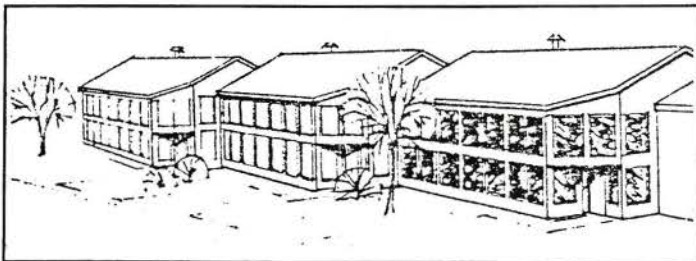
The goal of the greenhome would be to maintain relative humidity at levels near those optimum for the occupants, somewhere between 40% and 55%. No harmful condensation will result as long as potential condensation surfaces are maintained above the condensation temperature. On exposed North and West walls this is accomplished by placing the plywood wall sheathing on the inner $\frac{1}{8}$ of the wall and protecting it on the outside with 20 cm of insulation. Any condensation in the east and south sides will selectively and harmlessly take place on the single glazing of the sunspace.

During the past 3 years observations have shown that relative humidity within the Newfoundland Greenhome seldom varies from 50% ($\pm 5\%$). Generally speaking this has resulted in no condensation problems. This is probably due to the fact that exfiltration is discouraged and the walls and windows are relatively warm.

The only known condensation on the walls of the living space of the Newfoundland Greenhome is on and around the two windows which open directly to the outside. Such windows would be eliminated from the second generation Greenhome designs.

There are two other areas of condensation in the Newfoundland Greenhome that should be mentioned, the glazing of the Greenhouse and the walls of the unheated vestibule.

The vestibule shields the main entrance from the wind and also serves as a mudroom where visitors re-



South elevation (left) and north elevation (right) for the row house Greenhome.

move their winter boots and coats. This process of disrobing takes several minutes and considerations of politeness make it necessary to leave the door between the inside and the vestibule wide open during this time. Much warm moisture laden air flows into the vestibule and severe condensation takes place on the unheated walls and window.

This situation will be avoided in the second generation Greenhouses by placing the mudroom within the heated space, thus allowing for more rapid entry into the house and less loss of interior air into the sunspace.

Greenhouse Condensation

The greenhouse is the major site of condensation in the Newfoundland Greenhome. The glass remains clear during the day but films over at night. On winter nights this freezes and accumulates. In the morning the frost melts and runs off down the glass to gutters which carry the water off harmlessly. As much as 16 litres of water has collected on a single February night on the 100 M² of glazing.

Despite this high level of condensation the walls of the house itself remain completely dry. The reason for this is that saturated air in an enclosed space condenses selectively on the coldest surface.

As long as the designer accommodates his design to the inevitability of condensation on the greenhouse glass no harm will result. In fact this is considered to be an extremely positive feature of the greenhouse. By attracting and harmlessly eliminating excess moisture the house itself is protected.

Greenhouse condensation has another unexpected lifestyle benefit. During the day the condensation evaporates allowing a free view to the outside. As dusk falls a condensation curtain is pulled over the glass preventing outsiders from peering into the house.

The Dangers of Structural Condensation

While condensation on selected surfaces can be beneficial if it is expected and accommodated for, hidden and unplanned structural condensation can be disastrous. It is dangerous not only because it soaks the wood and insulation, bubbles the paint, etc. but also because it provides an ideal environment for wood fungi to grow. These fungi thrive best in warm wet wood in stagnant air conditions. In as few as 3 to 5 years these organisms can completely rot studs, sheathing and other structural components of a house.

Because there is insufficient heat in the short cool Newfoundland summer the walls fail to dry out, as a result they stay wet all year round. These are the worst conditions for structural rotting.

Structural condensation has become a severe threat to housing only in the last decade. It is associated with, but not caused by, increased insulation levels, increased structural tightness and a trend towards electrically heated flueless houses. Reports from Scotland (7) and Sweden (8) indicate that this is a severe problem in other countries that have cold damp climates.

The cause of structural condensation

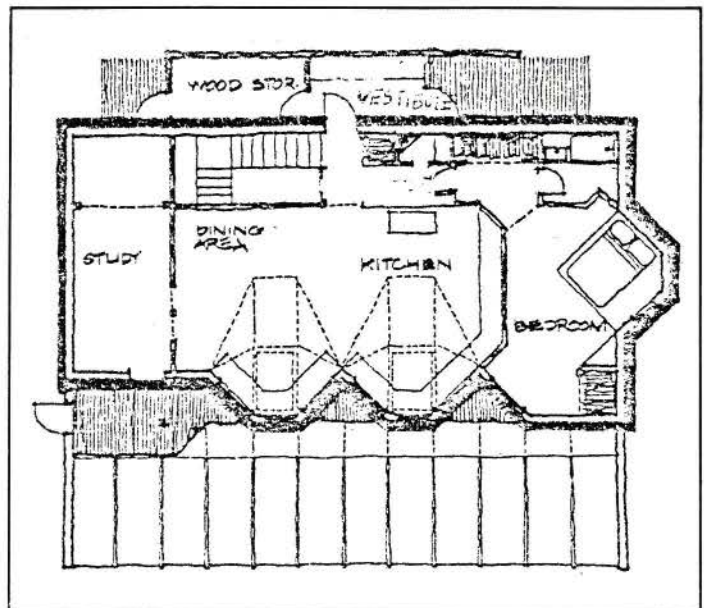
In Newfoundland the generally accepted mythology is that insulation causes condensation. This of course has no basis in fact.

Insulation has the effect of creating a steep temperature gradient across the thickness of a wall. The inner surface being close to room temperature while only 10 to 15 cm away the outer sheathing is close to the outside temperature. An examination of a psychrometric chart shows that inside air with a moderate relative humidity reaches and exceeds the saturation level when it is reduced to winter temperatures.

The point of disagreement is how the water gets to the sheathing. Does it diffuse out or does it get carried out with exfiltrating air? It is important to make this distinction because, depending on the answer, different preventative strategies should be used.

If one examined a cross section of an outside wall in winter one would find that the temperature gradient would fall towards the outside temperature, the relative humidity would rise towards 100% and the absolute humidity would remain level until just before the condensation surface. Diffusion pressure towards the outside is maintained only when the water vapor condenses out on a surface thus removing water from its vapor state. The alternative is that exfiltrating air flowing out through the wall carried water with it. On coming in contact with a cold enough surface condensation takes place.

It is likely that both processes can contribute to condensation but intuition suggests that exfiltration has the potential to carry far more moisture to a condensation surface than diffusion. Indirect evidence supports this conclusion. Condensation is usually worst where exfiltration has the greatest likelihood of occurring, high up on walls, on leeward wall, around doors and window



The vestibule shields the main entrance from the wind and also serves as a mudroom.

boxes, in back of electric boxes which have been set in holes slashed in the vapor barrier. Alternatively it is possible to find many examples of dry walls where the vapor barrier is either incomplete or entirely absent. This suggests that little condensation takes place in the absence of exfiltration. This would tend to argue against diffusion as the primary cause of condensation.

Despite this, the consensus is that diffusion causes condensation. Most modern books on house building and most government recommendations stress the importance of the vapor barrier as a means of reducing energy use and as a means of avoiding structural condensation. The vapor barrier is supposed to reduce energy use by slowing the rate of air exchange and it is supposed to prevent condensation by presenting, on the warm side of the wall, a barrier through which moisture cannot pass.

When structural condensation occurs the contractor is blamed for careless installation of the vapor barrier. Perhaps more blame should be placed on the designer and the government regulations which create situations in which condensation is almost inevitable.

A major assumption of the Greenhome design is that the main cause of condensation is exfiltration. The air tight north and western walls, the wind protected south and eastern walls and the stack ventilation are all strategies designed to eliminate exfiltration while simultaneously permitting adequate infiltration for ventilation purposes.

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ARCHITECTURAL ARCHIVES

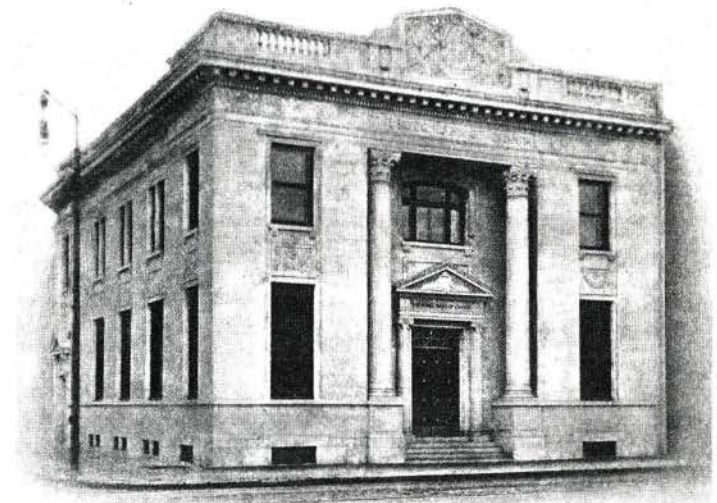
The Royal Bank of Canada Archives

William Curran, Archivist for the Royal Bank attended the 1983 SSAC Annual Meeting and has since provided the *Bulletin* with not only the cover illustration for this issue but also the following information.

The Royal Bank Archives were formally established in 1977 to preserve materials of permanent administrative and historical value. The collection is inclusive of all the bank's domestic and international operations. The holdings include corporate papers, publications, memorabilia and a photographic collection. Approximately 10,000 photographs of bank buildings, exterior and interior, are available. Negatives 4" x 5" are on hand for one half of the collection. In addition background information on the architects can be obtained. This also applies to buildings which were acquired by the Royal Bank with the amalgamations of other major Canadian banks, such as the Union Bank of Canada, The Quebec Bank and The Traders' Bank. Information can be retrieved geographically but also thematically, log cabins, pre-fab buildings, etc. Davenport and Pearson and Darling are the major architects represented.

The Archives are located at the Bank's Head Office in Montreal and is open to staff and members of the public from 9:30 to 4:30 Monday to Friday. It is closed on statutory and Bank holidays. A small museum is located within the Archives and visitors are welcome. Various reproduction services are available at the discretion of the Archivist. Researchers are requested to make an appointment.

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