

# **A MODEL FOR THE DESIGN AND EVALUATION OF ENERGY EFFICIENT NORTHERN HOUSING**

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## **ABSTRACT**

In addition to being a region of extreme cold temperatures with total darkness for almost half the year, the arctic territory of Nunavut suffers from, a housing shortage (in reality a crisis) that is the top of every political and economic agenda. In response to this crisis, the Nunavut Housing Corporation (NHC), in partnership with the Canada Mortgage and Housing Corporation (CMHC), initiated a design and development plan through the Infrastructure Canada program, to develop a sustainable solution to housing in the arctic. The result was the development of a new energy efficient housing project named the NHC 5-Plex.

This paper will examine and illustrate the design and development process undertaken by the NHC and CMHC for this project. The paper will describe how the integration of new construction materials and products, specifically designed for cold climates, strategic project management, and cooperation between the NHC and CMHC in the fields of design and building science were used to address the goals of energy efficiency and affordability for arctic housing. The paper will describe the process used to produce a multiplex public housing design that recognizes and compliments the life styles of the typical Inuit family, including insights into the occupants' level of acceptance of the design and the integration of their recommendations into the design of future public housing.

The study will illustrate the energy conservation calculations, the comparative and cost analysis used for the project, and provide insight into a design process which, working backwards from shipping delivery dates, supported the completion of 18 5-plex units by Dec. 2005. The paper will illustrate important issues for designers working on housing in cold climates, demonstrate the

use of new products and innovative construction methodology, and provide important insights for designers and builders everywhere who are interested in better performing and functioning buildings.

The paper will illustrate the success of this joint project between the NHC and CMHC, demonstrate the potential for improving the sustainability of housing in perhaps the harshest climate in the world, and highlight the importance of cultural sensitivity in the design process.

## **INTRODUCTION**

As principal supplier of the almost 9,500 housing units in the territory, the NHC is responsible for improving the housing and living conditions of the communities throughout Nunavut. For the NHC this includes the maintenance of 3,900 Public Housing units, the leasing or owning of 1,100 Staff Housing units and the holding of mortgages on approximately 500 homes. In total these represent 60 per cent of Nunavut's total housing stock. (NHC 2005). Housing is a major issue in Nunavut where the lack of sufficient housing has resulted in poor living conditions as a result of a 19% over-crowding rate, a level far higher than the 5% average for the rest of Canada. It is not uncommon to find homes, averaging less than 1000 square feet, with living spaces cramped by potable water storage tanks, washers/dryers, furnaces and hot water systems.

While the requirements for affordable northern housing combined the pressing needs to improve the energy efficiency of housing were key drivers of this project, the importance of addressing cultural design issues and providing for the needs of the Inuit was an integral part of the project. With this mandate, the NHC and CMHC began a joint exploration in alternate material, building science and design ideas to create the 2005 NHC 5-Plex, a row housing model designed as the Nunavut flagship for an energy efficient and culturally responsible housing design.

## METHODOLOGY

### NHC AND CMHC COLLABORATION

Previous to the 5-Plex project, CMHC provided technical assistance and energy modeling to the NHC on the design of an NHC 4-Plex, a row housing model designed to perform 25% better than the Model National Energy Code for Houses (MNECH). For this evaluation, the CMHC organized and chaired a review team that included housing researchers from CMHC, Natural Resources Canada (NRCan), that the National Research Council (NRC). Strategies developed and knowledge gained from the energy modeling exercise were incorporated by the NHC into the design for the 5-Plex.

### ENERGY MODELING

The energy modeling of the building performance for this project was undertaken through a technical and design review of the plans and construction details for the 4-Plex to be designed and built by the NHC. As part of this process, CMHC was responsible for the contacting and carrying out the evaluation of a thermal analysis of the 4-Plex design undertaken the NHC. The initial thermal analysis of the 4-Plex indicated that, using the proposed design and construction details, “the senior’s 4-plex units use 3% more energy for space heating than if designed to the MNECH”.<sup>1</sup> To bring the performance of the 4-Plex to a level that is 25% better than the MNECH, the review team developed a list building and mechanical details. These included:

- *Air tightness* - Improving air tightness to R-2000 levels (from the standard 3.2 ACH at 50 pa. to 1.5 ACH at 50 pa.)
- *Reducing envelope surface area* – Eliminating the heated crawl space in favour of a central utility room to service all four units.

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<sup>1</sup> A Review of Designs, Construction Specifications and a Thermal Analysis of Nunavut Housing Corporation 4-Plex Units, Canada Mortgage and Housing Corporation (CMHC), Dec. 2003. P. 3

- *Heating system changes/simplifications:* A single pump, with zone valves to each unit in the 4-plex.
- *Ventilation systems* – Install a balanced fan system with a heat recovery ventilation in a central unit with a duct system and fire-control dampers, or with individual HRV's in each unit
- *Windows* – Install high performance triple glazed windows
- *Electrical Usage* – Reduce usage through the installation of low electrical consuming lighting fixtures and appliances
- *Water Consumption* – Recognizing the high energy cost of delivering water in the north, the use of low flow fixtures water fixtures for all installations

In addition to incorporating these features into the design of the 4-Plex, these features were carried over to the design of the NHC 5-Plex.

#### **THE NHC 5-PLEX**

The design and working drawings for the 5-Plex were prepared by the NHC with recommended alterations evolving from meetings of a committee that including the technical group of the NHC and the Senior Researchers of the Housing Technology Group at CMHC, a working group set up specifically to provide technical and design input into this project. Throughout the project, issues of affordability and the cost of construction in the arctic, energy efficiency, and Inuit cultural needs were important drivers. Drawing upon the technical and design experience of the NHC and design and research experience of the CMHC, the work of the committee included:

- Evaluating and recommending materials (windows, insulation etc.) to improve building performance and or reduce shipping costs

- Evaluating construction details for energy efficiency, flame ratings, combustibility, sound transmission and water permeability
- Evaluating the heating and ventilation strategy for the units.
- Carrying out a design review of culturally sensitive design details in order to better adapt the proposed design to the unique needs of Inuit families. Recommendations and strategies from these meetings generated were utilized by the NHC to generate the final plans and details for the 5-Plex.

An ongoing and open dialogue was maintained between the NHC and the CMHC throughout the project as the NHC continued to refine the 5-Plex designs. Construction details were meticulously reviewed by CMHC to ensure energy performance and durability of the units would be maintained. Upon completing a final construction document package, the plans were given a final careful review by the NHC and the CMHC. Upon satisfaction of all parties expectations, the newly designed energy efficient social housing 5-Plex (Figure 1) was ready to go out to tender.



*Figure 1: Completed NHC 5-Plex in Arviat, Nunavut*

#### **ENERGY EFFICIENCY CONSIDERATIONS**

The importance of designing and developing a social housing complex that would exceed existing standards of energy efficiency in housing (i.e. 25% better than MHECH) was an essential component of this project. From the energy modeling carried out on a 4 – Plex (designed by the

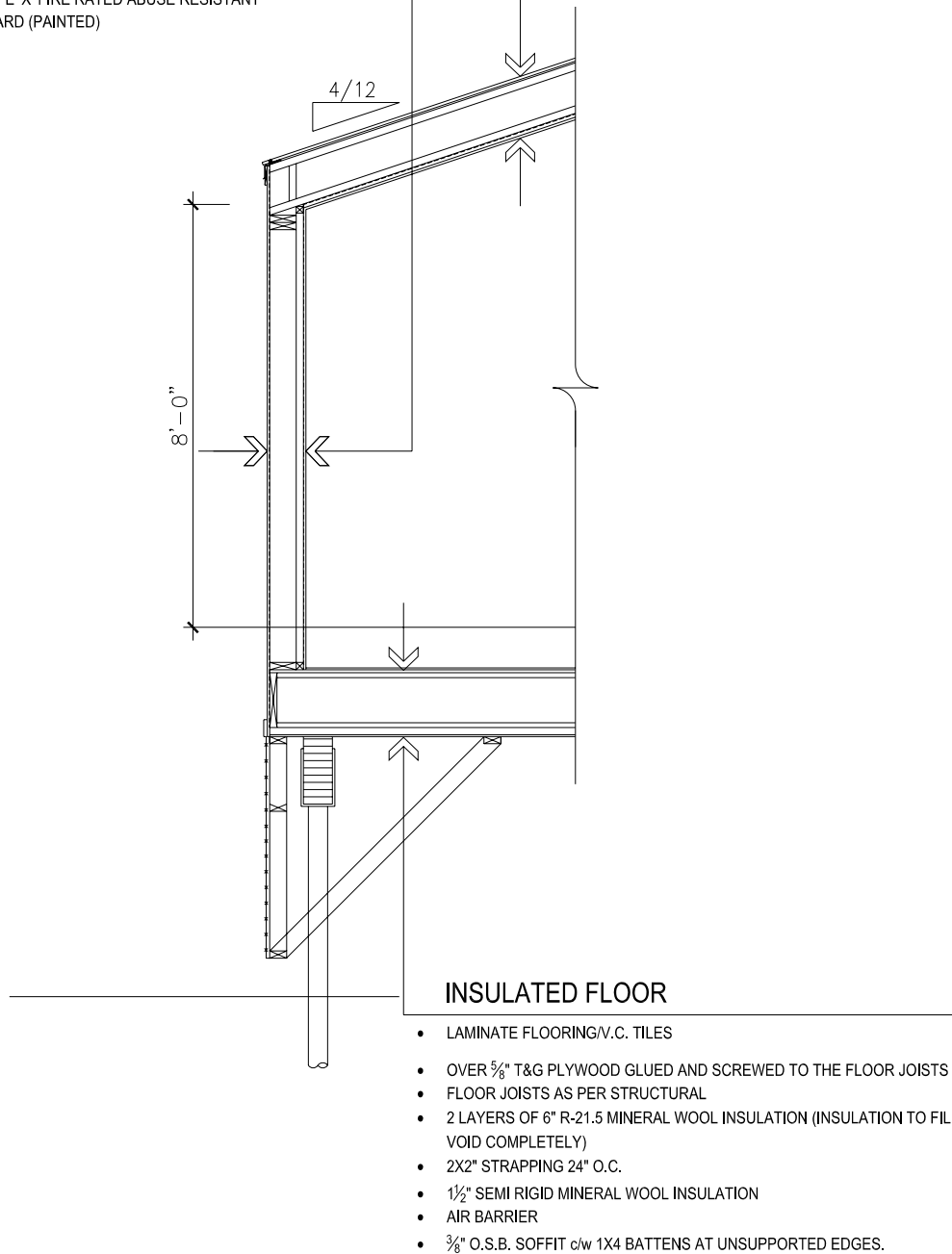
## EXTERIOR WALL CONSTRUCTION

- LP SMARTSIDE PANEL SIDING
- AIR BARRIER
- 2X6 WOOD STUDS @ 16" o.c.
- 5½" R-21.5 MINERAL WOOL INSULATION
- 6 MIL POLY VAPOUR BARRIER
- 2X2 STRAPPING @ 24" o.c.
- 1½" R-7 SEMI RIGID INSULATION
- ½" ABUSE RESISTANT GYPSUM BOARD (PAINTED)

NOTE: EXTERIOR WALLS AT MECHANICAL ROOM AND WATER TANK ROOM ½" TYPE 'X' FIRE RATED ABUSE RESISTANT GYPSUM BOARD (PAINTED)

## TYPICAL ROOF CONSTRUCTION

- METAL ROOF
- 1X4 STRAPPING @ 24" o.c.
- ¾" PLYWOOD SHEATHING WITH GRACE MEMBRANE AT SEAMS
- TJI JOISTS AS PER SPEC.
- 2 LAYERS 6" R-21.5 MINERAL WOOL INSULATION (INSULATION TO FILL VOID COMPLETELY)
- VAPOUR BARRIER
- 1X4 STRAPPING AT 16" OC
- ½" GYPSUM BOARD (ABUSE RESISTANT)



## INSULATED FLOOR

- LAMINATE FLOORING/V.C. TILES
- OVER 5/8" T&G PLYWOOD GLUED AND SCREWED TO THE FLOOR JOISTS
- FLOOR JOISTS AS PER STRUCTURAL
- 2 LAYERS OF 6" R-21.5 MINERAL WOOL INSULATION (INSULATION TO FILL VOID COMPLETELY)
- 2X2" STRAPPING 24" O.C.
- 1½" SEMI RIGID MINERAL WOOL INSULATION
- AIR BARRIER
- ¾" O.S.B. SOFFIT c/w 1X4 BATTENS AT UNSUPPORTED EDGES.

Figure 2: Construction Details (drawings by NHC)

NHC and evaluated by CMHC) and the evaluation of the building details of the 5 – Plex carried out as part of this exercise (Figure 2) by the committee concluded that the R values and air tightness values as designed were quite good and should meet the targets for the project (25% better than the MNECH). In addition to this review, several alternate construction material and building science innovations were incorporated as part of this exercise including:

- Specifying triple pane low-E, argon fibre-glass windows throughout the entire complex for both energy efficiency and durability.
- Removing individual utilities in each unit to a central utility room, providing hydronic heating, and water storage for all 5 units.
- Addressing the ongoing issue of indoor air quality and energy efficiency, an HRV (Heat Recovery Ventilator) was integrated into a fresh air intake in an insulated attic space in each unit to provide the ventilation, control humidity levels of the interior and prevent mold and mildew problems and heat recovery.
- The introduction of the ‘Arctic Vent’, a hydronically heat traced vent cap to prevent the buildup of snow and ice around the vent, savings on maintenance. The maintenance of frozen passive soil stack vents from the continuous exhausting vapors and resulting freeze-up is an ongoing and costly maintenance problem.

### **Affordability and the Cost of Construction in the Arctic**

In the Arctic, construction costs are elevated by the cold climate and its effects on the efficiency and schedule of the labour force, and the lack of road or rail transport. The transport of construction materials into the communities of Nunavut is carried out by costly and time consuming sea lift services once per year (Figure 3), with bulk deliveries arriving from the southern provinces via sea bearing barges. The items forgotten on those shipments or for emergencies the costlier option is to have items delivered via air freight. With most of Nunavut



*Figure 3: Sea Lift Materials and a 5-Plex's Under Construction in Arviat*

well above the tree-line, conventional natural resources for construction are extremely scarce, leaving importing as the only option. As a result of these realities, careful consideration was given by the committee to the selection of materials that could potentially reduce shipping costs while not compromising on building performance.

Innovations included:

- Heavy building members such as 2x4 and 2x6 solid wood studs for interior walls were replaced with significantly lighter steel studs, generating a savings in material cost as well as a considerable savings on freight
- Reducing materials by simplifying the design of the interior (no corridors or jagged walls) to reduce the use of materials efficient use of building materials, the potential for misunderstandings by contractors interpretation of design details in remote locations, and the potential negative impact on scheduling and construction costs (Figure 4).
- Reducing materials by optimizing framing details and removing the heated crawl space (Figure 5) typical of northern construction, an area of physical volume equivalent to an nearly a half floor of additional heated space. The utilities would be moved to a separate utility room in the complex, with HRV's installed in a small and easily accessible heated attic space in each unit.

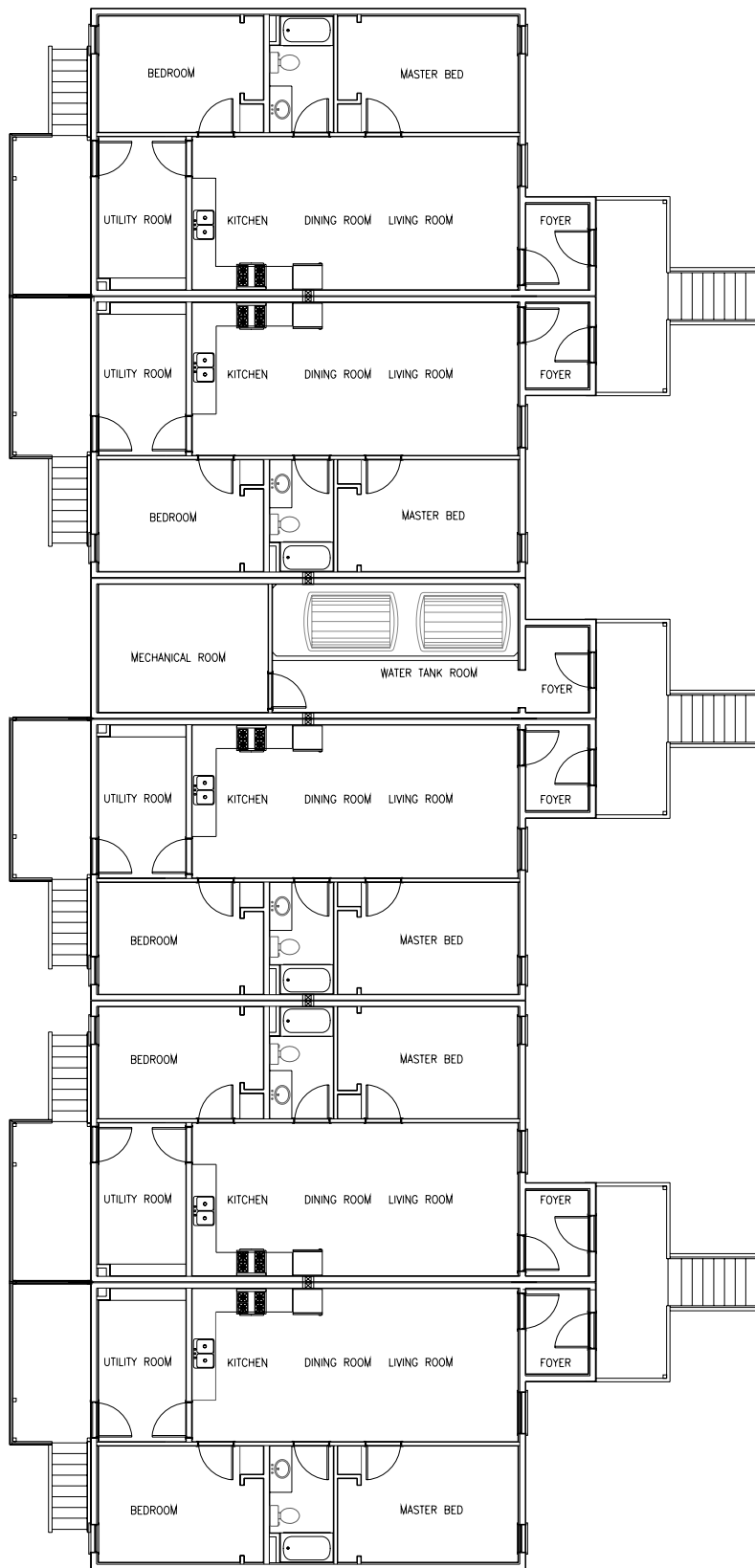


Figure 4: 5 Plex Floor Plan (drawing by NHC)



*Figure 5: Construction Details*

### **Addressing Inuit Cultural Needs**

For the NHC and CMHC, through experience, integrating traditional cultural values into housing has become an important part of using the design process to address the specific and unique spatial needs in houses of the typical Inuit family. Utilizing NHC experience and CMHC research, the following culturally related amenities were integrated into the NHC 5-Plex housing design:

- Designing the floor plan based on an open concept to accommodate traditional Inuit values revolve of family and community where it is not uncommon for several generations to gather and share meals together in larger open spaces. The more open concept allows family gatherings to expand from the living area into the dining and kitchen, uninterrupted by partitions of any kind (Figure 6).
- Including deeper customized cabinetry in the kitchen to for the storage of large cooking pots commonly used to in preparing large family meals of large game.

- Providing space for the Inuit cultural activity of hunting and preparing wild game, a special wild game preparatory station, complete with stainless steel cutting table and washing sink, was designed in combination with a rear entrance to the house (see Floor Plan Figure 4).



*Figure 6: Open Floor Plan*

#### **PROJECT PLANNING AND DELIVERY**

To successfully carry out this project, the NHC/CMHC working committee had to ensure that the timing of it's' work responded to the needs of the northern construction process. In the Arctic, an almost non-existent summer season leaves a small window for construction where, in most communities, the first snowfall often arrives along with the sealift ship from the south. As a result, a two year delivery cycle, the practice of building units in the construction season following the delivery of the necessary materials, is becoming common practice in Nunavut. This practice, which was used in the consultation process of the 5-Plex project, required careful planning and project management on the part of the NHC, with the design committee working to the dates set out by this shipping and materials management process. This involved estimating the departure date for the shipment and working backwards, including loading time on the docks, marshalling time for material suppliers, an appropriate time for the tender process, contract documentation and packaging, advertising the tender, etc. The time estimate included the

preparation of all components of the pre-construction phase, including preliminary and final design, structural, electrical and mechanical consultations, and drawing review by authorities, with all aspects of the process having a potential impact on the shipping process.

#### **POST CONSTRUCTION**

The first delivery brought 18 new NHC 5-Plex's to provide much needed housing for communities throughout Nunavut. The 2006/2007 construction season has currently tendered 22 new 5-Plexs with materials set to arrive in communities by mid September 2006.

#### **CONCLUSIONS/RECOMMENDATIONS**

Rapidly rising energy costs, the need for capacity development within northern communities and the potential and challenges of new technologies for energy, construction etc. are ongoing issues for northern housing agencies. The rapidly growing population in combination with changing cultural needs is an additional challenge that is in need of more attention in many northern communities. Recognizing the sense of urgency resulting from the rising cost of energy in the north and the impact of buildings on the environment, the committee made a number of recommendations that were designed to make further improvements to the energy performance of the 5 - Plex. Increasing the R values on a future 5 plex and monitoring the energy savings (to determine payback) was strongly recommended. Suggested details to accomplish this include:

- Adding a minimum of 1½" of rigid insulation to the exterior wall
- Strapping (2" x 2" or 2" x 3") and insulating the inside of the ceiling.
- Examine the potential of utilizing a combination of framing and SIP's as a wall system
- Adding an air lock entrance to the rear doorway
- Addressing zoning restrictions and their impact on set-backs etc. as these appear to be a limiting factor to including larger and more spacious entrances for storage etc.

- Exploring the design and construction of what a really good ‘Arctic Entry’ would be. Some Ideas to explore include: designing the entrance including floor drainage for the snow and ice brought in (to reduce interior humidity levels).
- Using a southern orientation wherever possible for the siting of all future housing units. This will provide additional energy efficiency and allow for the installation of solar technologies as they are refined for northern applications.
- Exploring the idea of enclosing external front entrance stairways in an atrium space to create a shared indoor area. This includes housing cluster designs that would allow the incorporation of shared sheltered passive solar spaces.

The collaboration between the NHC and the CMHC was a vital element to the success of this project. The success of this design initiative was based on the open and cooperative relationship between the NHC and the CMHC. The NHC brought their technical and design experience with northern housing and construction methodologies, and extensive experience with building components and their success and failure in the extremely cold climates of the arctic. The CMHC brought considerable knowledge and background on building science, research of new and energy efficient building materials, and experience in working with communities, builders and others in addressing sustainable building issues. It is anticipated that continued open communication between the two organizations will continue to produce exceptional innovations in efficiency of housing design, and building science research on northern housing. Collaboration on other projects is being planned.

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