RESEARCH REPORT

External Research Program

Cost-Effective Indoor Air Quality and Energy Efficiency Recommendations for First Nations Housing

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Cost-Effective Indoor Air Quality And Energy Efficiency Recommendations For First Nations Housing

Final Report

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Foreword

Purpose

The purpose of this research project was to do the following:

- Prove that less capital investment in First Nations housing but acceptance of higher costs incurred over the life cycle of a house is not cost-effective;
- Demonstrate the potential for cost-effective, improved housing in First Nations communities;
- Prove that indoor air quality (IAQ) improvements and energy efficiency (EE) improvements can be compatible and cost-effective;
- Demonstrate the value of investigations according to the CMHC IAQ Investigative Protocol and the Energuide for Houses Evaluation Protocol as repeatable, effective renovation planning methods based on the house as a system;
- Raise the level of acceptance for future recommendations from First Nations IAQ investigators trained according to the CMHC protocol;
- Raise the level of acceptance for renovation recommendations suggested by regional delivery agents of the Energuide for Houses Program; and
- Transfer recommendations from this project, complete with well-documented examples, to First Nations communities, particularly the Washagamis Bay and other northwest Ontario First Nations.

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Executive Summary

Purpose

The purpose of this research project was to prove that less capital investment in First Nations housing but acceptance of higher costs incurred over the life cycle of a house is not cost-effective; to demonstrate the potential for cost-effective, improved housing in First Nations communities; and to demonstrate the value of investigations according to the CMHC Indoor Air Quality Investigative Protocol and the Energuide for Houses Evaluation Protocol as repeatable, effective renovation planning methods that could be implemented by First Nations technical service providers.

The Investigations

Indoor air quality (IAQ) investigations and house energy efficiency (EE) evaluations, according to the recognized protocols noted above, were conducted on five sample houses volunteered by the Washagamis Bay First Nation. A community member with housing responsibilities and an interest in inspection training assisted during the investigations.

The houses were numbered in the order that they were investigated. House 1 is a small bungalow with a preserved wood crawl space foundation, built in 1990. House 2 is one half of a single storey duplex with a preserved wood crawl space foundation, built in 1999. House 3 is a small bungalow with a concrete block foundation, built in 1970. House 4 is a one and a half storey frame home with a full, shallow, preserved wood foundation. House 5 is composed of two parts: a bungalow with a preserved wood pier crawl space foundation, built in 1990, attached to a similar sized bungalow with a concrete block crawl space foundation, built in 1970.

Lower, medium and higher cost indoor air quality recommendations were developed along with recommendations to improve energy efficiency. The capital costs of the recommendations were estimated. The resulting IAQ and EE recommendations were linked together, along with other renovation needs that became apparent during the investigation of these houses. The renovation plans and costs were reviewed and approved by the resource coordinator of the Washagamis Bay First Nation.

Current Construction Practices

Current construction practices have led to unnecessary energy costs, poor indoor air quality and premature building failure. These practices include:

- Preserved wood foundations built directly on concrete footings with no capillary breaks;
- No perimeter drainage around the foundations or granular drainage layers inside the foundations;
- Un-insulated footings exposed above grade;
- Uncovered dirt floors in crawl spaces;
- Poor or non-existent interior air/vapour barriers covering crawl space wall insulation;
- Incomplete main living area air/vapour barriers;
- Unsafe heating system installations;
- Poor exhaust of moisture and pollutants;
- No mechanical supply of fresh air;
- Poor heat and air circulation within the houses;
- Inadequate testing of plumbing systems; and

- Building to a standard that does not meet the prescriptive requirements of the National Building Code of Canada 1995 or the Model National Energy Code of Canada for Houses 1997.

Building envelopes have become better insulated and more airtight over the years. However, none of the four houses with crawl spaces has a moisture barrier to cover the dirt floor. Mechanical ventilation systems are limited to bathroom fans (except for a blocked fresh air supply duct in house 4). With the exception of the forced air furnace in house 4, mechanical air circulation is limited to ceiling fans. Two out of three new pellet stoves are sidewall vented but that venting has not been installed according to the manufacturer's guidelines. The centrally located box stove in house 5 has insufficient clearance to combustible materials.

As a result, none of the houses is as durable as it could be. The 'house as a system' approach has not been used in the construction of any of the homes. House 2, built in 1999, is better insulated and more airtight than the houses built from 1970 to 1990. However, it is no more durable and has no more potential to provide good indoor air quality.

From this small study, it appears that it is not only the level of capital investment that dictates the quality of housing. In all of the houses, better specifications and increased capital expenditure would have been required at the time of construction to provide improved heating, ventilating and building envelope insulation values. However, other deficiencies, such as lack of drainage, no crawl space floor moisture barriers, poor air/vapour barriers, leaky plumbing and dryers that vent into crawl spaces could have been completed properly during construction for little extra cost.

The Cost Analysis

For each house, first the building envelope and mechanical system recommendations that would improve energy efficiency and ventilation were considered before adding costs for other needed repairs to items such as unsafe porches, interior damage and poor grading. The energy costs estimated for the proposed houses after renovation were compared to the energy costs of the existing homes. They were also compared to the energy costs of the existing houses as if they had total airchange rates similar to the airchange rates proposed for the renovated homes. Dividing the estimated capital costs of the proposed renovations by the estimated annual energy cost savings provided a straight payback period calculation. Other costs, such as financing and tax increases after renovation, were not considered because these houses are in a First Nations community and are owned by the band. Renovation costs are expected to be part of the annual housing budget.

In the first house, it would take 5.1 years for the anticipated annual energy savings of $391 to recover the $1,986 cost of the proposed IAQ and EE renovations. If the comparison were based on similar airchange rates, the payback period would be only 4.5 years. However, renovations are also needed for safety, durability and damage repairs, escalating the total cost to $9,996. The total renovation costs would take 25.6 years to recover through energy savings.

For house 2, which already has a better-insulated building envelope, the capital cost of $5,599 for IAQ and EE renovations would be recovered in 23.0 years by annual energy savings of $243. If the comparison were made on similar airchange rates, the payback period would be 16.3 years. Other needed renovations would escalate the capital cost to $8,504. The total renovation costs would take 35 years to recover through energy savings.

House 3 is older, in relatively poor condition and with less monetary value. Only minor renovations costing $1,345 were recommended to ensure reasonable durability and comfort until the house can be replaced. Very little energy saving is expected.

House 4 is a much more expensive home that should be enhanced and preserved through the installation of heat recovery ventilation. Mechanical ventilation, even with heat recovery, increases heating costs. The capital cost of heat recovery ventilation through a simplified duct system, along with an energy efficient furnace fan to distribute the supply of fresh air through the existing forced air heating system, is estimated at $2,300. The expected annual energy cost increase is $184. If the comparison were based on similar total airchange rates, non-heat recovery ventilation distributed with a standard furnace fan, at a capital cost of $900, would increase annual energy costs by $491. By spending the extra $1,400, annual energy savings of $307 would recover the investment in 4.6 years, well within the expected lifespan of the house and equipment. Other needed renovations would escalate the total cost to $3,342.

House 5 is in such poor condition that re-location of the occupant is recommended.

Extensive renovations are proposed only for houses 1 and 2. The renovations to house 4 are straightforward. For these three houses, the most significant renovation benefits expected are greater durability and improved indoor air quality.

The Potential for Cost Effective Improved Housing

Indoor air quality in the existing houses could be somewhat improved with little expense. The home occupants could be encouraged and trained to implement at least half of the no cost or lower cost recommendations.

Almost the entire lists of medium cost and higher cost indoor air quality recommendations would also improve energy efficiency and building durability. Recommendations for these three purposes are clearly compatible.

House 2 is the only house built after the Model National Energy Code of Canada for Houses 1997 was published. If this house had been built to the prescriptive standards of that code, energy costs would be lower than for the current unventilated house. Indoor air quality and house durability would also be far superior. This house is likely to fail prematurely unless it is upgraded soon.

The reduced energy consumption attributable to the wood pellet stoves does not justify the required capital costs, fuel storage and fuel handling. Capital required for future installations would be better spent on building envelope and ventilation improvements. Houses with better building envelopes also survive power outages longer before needing alternative energy for heating.

Many of the recommendations made are not only related to indoor air quality or energy efficiency. Drainage, finish of incomplete houses, safety, durability and damage repairs are all issues that need to be addressed. Total renovation costs are much higher when these items are included. Energy cost savings can provide some payback but they cannot completely finance renovations that must be done for deficiencies unrelated to energy consumption. The most important reasons to renovate houses deficient in other areas are saving of the capital already invested and provision of a healthier, safer living environment for the occupants.

Effective Renovation and New Construction Planning

First Nations technical service providers could follow the two protocols used in this report to analyze existing and proposed houses. However, the first step would be to build to specifications based on the prescriptive standards of the National Building Code of Canada 1995 and the Model National Energy of Canada for Houses 1997. Thorough pre-occupancy inspection of new houses is essential.

Further Research

1. Develop house specifications based on the prescriptive standards described above.

2. Complete the renovations according to the recommendations in this report. Record the actual costs. Complete a second indoor air quality and energy evaluation of each house after renovation. Analyse the data to reveal the degree of success attained and any shortcomings in the evaluation methods, cost estimates or on-site completion of the work as specified. Develop recommendations designed to help ensure the success of future renovation projects.

3. Match the allocation of housing funding in a community over a particular time period to the state of the housing that was created or renovated due to that spending. Determine what successes or failures exist. Develop recommendations to allow future spending to be more cost effective.

Conclusions

In this small sample, the house built in 1999 is no more durable nor does it provide better indoor air quality than the houses built from 1970 to 1990.

Houses are not being built to nationally accepted standards nor are they being completed. Building to the prescriptive standards of the National Building Code of Canada 1995 and the Model National Energy Code of Canada 1997 is recommended.

Using the CMHC IAQ Investigative Protocol, the Energuide for Houses evaluation system and a checklist based on the above prescriptive standards, First Nations technical service providers could develop recommendations for existing houses and for new construction. Because many deficiencies are related to safety, durability, drainage and damage repairs, estimated energy cost savings would not recoup the capital outlay for all needed renovations within a reasonable time period. However, lower energy costs would help to offset necessary capital expenditures. The renovated houses would last longer, be more comfortable and would provide better indoor air quality.

Résumé

Objet

Ce projet de recherche a pour objectif de démontrer qu'il n'est pas efficient de réduire les dépenses en immobilisations dans le logement des Premières nations, mais de permettre des coûts plus élevés au cours de la durée utile de la maison; de démontrer la possibilité d'améliorer et de rendre plus efficient le logement dans les collectivités des Premières nations et de démontrer que le protocole d'investigation sur la qualité de l'air intérieur et le protocole d'évaluation des maisons ÉnerGuide sont des méthodes d'investigation et de planification reproductibles et efficaces en matière de rénovation qui peuvent être appliquées par les fournisseurs de services techniques des Premières nations.

Les investigations

Des investigations sur la qualité de l'air intérieur (QAI) et des évaluations de l'efficacité énergétique (EE) conformes aux protocoles reconnus susmentionnés ont été réalisées sur un échantillon de cinq maisons proposées par la Première nation de Washagamis Bay. Un membre de la collectivité détenant des responsabilités dans le domaine du logement et possédant un intérêt pour une formation en inspection a apporté son aide au cours des investigations.

Les maisons ont été numérotées dans l'ordre selon lequel elles ont été inspectées. La maison n° 1 est un petit bungalow, construit en 1990, possédant une fondation en bois traité avec vide sanitaire. La maison n° 2, construite en 1999, fait partie d'un duplex d'un étage possédant une fondation en bois traité avec un vide sanitaire. La maison n° 3, construite en 1970, est un petit bungalow avec fondation en blocs de béton. La maison n° 4 est une habitation d'un étage et demi à ossature de bois ayant une fondation en bois traité complète et vide. La maison n° 5 est constituée de deux parties : un bungalow, construit en 1990, possédant une fondation sur piles de bois traité avec vide sanitaire jumelé à un bungalow de taille similaire, construit en 1970, possédant une fondation en blocs de béton avec vide sanitaire.

On a recommandé des mesures d'amélioration de la qualité de l'air intérieur à coût faible, moyen et élevé ainsi que des mesures d'amélioration de l'efficacité énergétique. On a estimé les frais en immobilisations associés à ces mesures. On a ensuite combiné les recommandations sur la QAI et l'EE ainsi obtenues, ainsi qu'avec d'autres besoins de rénovation qui s'étaient révélés au cours de l'inspection de ces maisons. Le coordonnateur des ressources de la Première nation de Washagamis Bay a examiné et approuvé les plans et les frais de rénovation.

Pratiques de construction courantes

Les pratiques de construction courantes entraînent des frais d'énergie inutiles, une piètre qualité de l'air intérieur et la défaillance prématurée de l'immeuble. Ces pratiques se caractérisent notamment par :

- la construction de fondations en bois traité directement sur les semelles de béton sans rupture capillaire;
- l'absence de drainage autour des fondations ou de couches de drainage granulaires à l'intérieur des fondations;
- des semelles non isolées exposées au-dessus du sol;
- un plancher en terre battue non couvert dans les vides sanitaires;
- une absence ou une mauvaise qualité des membranes d'étanchéité intérieure couvrant l'isolation des murs du vide sanitaire;
- des membranes d'étanchéité incomplètes autour de l'aire habitable;
- un système de chauffage non sécuritaire;
- une évacuation médiocre de l'humidité et des polluants;
- une absence de système mécanique d'alimentation en air frais;
- une mauvaise circulation de la chaleur et de l'air à l'intérieur des maisons;
- des systèmes de plomberie mal testés;
- une construction qui ne respecte pas les exigences du Code national du bâtiment du Canada (1995) ou du Code modèle national de l'énergie pour les habitations (1997).

Au cours des années, les enveloppes du bâtiment sont devenues mieux isolées et plus étanches à l'air. Toutefois, aucune des quatre maisons comportant un vide sanitaire n'avait de revêtement de protection contre l'humidité couvrant le plancher en terre. Les systèmes de ventilation mécanique se limitent à des ventilateurs de salle de bains (à l'exception d'une conduite d'alimentation en air frais dans la maison n° 4). À l'exception du générateur d'air pulsé de la maison n° 4, la circulation mécanique de l'air se limite à des ventilateurs de plafond. Deux des trois poêles à granules de bois ont une prise d'air murale, mais cet élément de ventilation n'a pas été installé selon les directives du fabricant. Le poêle de type « truie » situé au milieu de la maison n° 5 est trop près de matériaux combustibles.

Il résulte de ces constatations qu'aucune des maisons n'a la durabilité qu'elle pourrait avoir. On n'a pas utilisé de méthodes systémiques de construction pour aucune d'entre elles. La maison n° 2, construite en 1999, est mieux isolée et plus étanche que les maisons construites de 1970 à 1990. Toutefois, elle n'est pas plus durable et n'offre pas une bonne qualité d'air intérieur.

Il découle de cette petite étude que ce n'est pas seulement le niveau des dépenses en immobilisations qui régit la qualité des logements. Dans chacune des maisons, de meilleures spécifications et des dépenses en immobilisations plus élevées auraient été nécessaires au moment de la construction pour améliorer le chauffage, la ventilation et les caractéristiques d'isolation de l'enveloppe du bâtiment. Toutefois, d'autres défauts, comme le manque de drainage, l'absence de membranes d'étanchéité dans les vides sanitaires, la médiocrité des membranes d'étanchéité, des fuites de la tuyauterie et des sorties de sécheuse dans les vides sanitaires, auraient pu être évités à peu de frais au cours de la construction.

Analyse des coûts

Pour chaque maison, on a commencé par considérer les recommandations touchant l'enveloppe du bâtiment et le système mécanique qui amélioreraient l'efficacité énergétique et la ventilation avant d'ajouter des coûts pour d'autres réparations nécessaires (p. ex., balcons dangereux, dommages intérieurs, mauvais nivellement). On a comparé les frais d'énergie estimatifs des maisons après les rénovations avec les frais d'énergie des maisons actuelles. On les a également comparés avec les frais d'énergie des maisons existantes dans le cas où leur taux de renouvellement d'air serait semblable à celui proposé pour les maisons rénovées. En divisant les frais en immobilisations estimatifs des rénovations proposées par les économies annuelles estimatives de frais d'énergie, on obtient un calcul direct de la période de récupération. D'autres frais, comme les frais de financement et les hausses d'impôt après rénovation, n'ont pas été considérés parce que ces maisons font partie d'une collectivité des Premières nations et qu'elles appartiennent à la bande. On s'attend donc que les frais de rénovation seront intégrés au budget annuel d'habitation.

Dans le cas de la maison n° 1, il suffirait de 5,1 ans pour que les économies d'énergie annuelles anticipées de 391 $ permettent de récupérer les frais de 1 986 $ engagés pour les rénovations au chapitre de la QAI et de l'EE. Si la comparaison est basée sur des taux semblables de renouvellement de l'air, la période de récupération serait de seulement 4,5 ans. Toutefois, des travaux s'avèrent nécessaires pour réparer certains dommages et assurer la sécurité et la durabilité du logement, ce qui fait grimper le coût total à 9 996 $. À ce niveau, il faudrait 25,6 années pour récupérer le coût total des rénovations au moyen des économies d'énergie.

Dans le cas de la maison n° 2, qui dispose d'une enveloppe du bâtiment mieux isolée, les frais en immobilisations de 5 599 $ pour les rénovations de type QAI et EE seraient récupérés en 23 années au moyen des économies d'énergie annuelles de 243 $. Si la comparaison est fondée sur des taux semblables de renouvellement de l'air, la période de récupération serait de 16,3 ans. Si l'on apporte les autres rénovations nécessaires, les frais en immobilisations atteignent 8 504 $. Il faudrait alors 35 ans pour récupérer ces frais totaux grâce aux économies d'énergie.

La maison n° 3 est plus ancienne, son état est relativement mauvais et sa valeur est moindre. C'est pourquoi on ne recommande que des rénovations mineures de 1 345 $ pour assurer une durabilité et un confort raisonnables jusqu'à ce que la maison soit remplacée. On ne prévoit que très peu d'économies d'énergie.

La maison n° 4 est une maison beaucoup plus coûteuse qu'il vaut la peine d'améliorer et de préserver en installant un système de ventilation avec récupération de chaleur. Toutefois, la ventilation mécanique, même si elle est assortie d'une récupération de chaleur, accroît les frais de chauffage. On estime à 2 300 $ les frais en immobilisations d'un système de ventilation à récupération de chaleur comprenant un réseau de conduits simple ainsi qu'un ventilateur de générateur éconergique permettant de distribuer l'air frais dans le système de chauffage à air pulsé. On prévoit que l'augmentation annuelle des frais d'énergie serait de 184 $. Si la comparaison se fonde sur des taux semblables de renouvellement de l'air, un système de ventilation sans récupération de chaleur associé à un ventilateur de générateur standard nécessitant des frais en immobilisations de 900 $ augmenterait les frais d'énergie annuels de 491 $. En dépensant les 1 400 $ additionnels, les économies annuelles d'énergie seraient de 307 $, ce qui permettrait de récupérer l'investissement en 4,6 ans, soit en beaucoup moins de temps que la durée utile prévue de la maison et du matériel. Si l'on apporte les autres rénovations nécessaires, le coût total grimperait à 3 342 $.

La maison n° 5 est dans un état tel que l'on recommande que les occupants soient relogés.

On ne propose de gros travaux de rénovation que pour les maisons n^os^ 1 et 2. Dans le cas de la maison n° 4, les rénovations sont simples. Pour ces trois maisons, les avantages les plus importants sont une plus grande durabilité et une meilleure qualité de l'air intérieur.

Possibilité d'une amélioration efficiente du logement

Il est possible d'améliorer quelque peu la qualité de l'air intérieur dans les maisons existantes à peu de frais. On pourrait encourager et former les occupants pour qu'ils puissent apporter au moins la moitié des mesures à faible coût ou gratuites.

Presque toutes les recommandations visant la qualité de l'air intérieur moyennant un coût moyen ou élevé amélioreraient également l'efficacité énergétique et la durabilité du logement. Les recommandations visant ces trois objectifs sont clairement compatibles.

La maison n° 2 est la seule habitation construite après la publication en 1997 du Code modèle national de l'énergie pour les habitations. Si la maison avait été bâtie selon les normes de ce code, les frais d'énergie seraient moins élevés que ce qu'ils sont dans la maison actuelle non ventilée. De plus, la qualité de l'air intérieur et la durabilité de la maison seraient également supérieures, et de loin. Des problèmes pourraient subvenir de façon précoce dans cette maison, à moins qu'elle ne soit prochainement mise à niveau.

La réduction de la consommation d'énergie découlant de l'utilisation d'un poêle à granules de bois ne justifie pas les frais en immobilisations qu'il faut engager, de même que l'entreposage et la manutention du combustible que cela nécessite. Il serait plus judicieux de consacrer cet argent à améliorer l'enveloppe du bâtiment ou le système de ventilation. Les maisons possédant une enveloppe du bâtiment améliorée résisteront plus longtemps à une panne de courant avant qu'il ne soit nécessaire de faire appel à une autre source de chauffage.

Beaucoup des mesures recommandées ne se rapportent pas uniquement à la qualité de l'air intérieur ou à l'efficacité énergétique. Il faut également s'occuper de problèmes comme le drainage, la finition de maisons non achevées, la sécurité, la durabilité et la réparation des dommages. Les dépenses de rénovation totales sont beaucoup plus élevées lorsque de tels éléments sont inclus. Les économies d'énergie peuvent permettre de récupérer une partie ces coûts mais elles ne permettent pas de financer complètement les travaux qui doivent servir à corriger des défaillances sans relation avec la consommation d'énergie. Les raisons les plus importantes de rénover les maisons déficientes sous d'autres aspects sont la préservation du capital déjà investi et l'aménagement d'un milieu de vie plus sain et plus sûr pour les occupants.

Planification efficace de travaux de rénovation et de construction

Les fournisseurs de services techniques des Premières nations pourraient suivre les deux protocoles appliqués pour la présente étude afin d'analyser les maisons existantes et proposées. Toutefois, la première tâche consisterait à construire les maisons selon les spécifications fondées sur les normes prescriptives du Code national du bâtiment du Canada (1995) et du Code modèle national de l'énergie pour les habitations (1997). De plus, il est essentiel de procéder à une inspection détaillée des maisons neuves avant leur occupation.

Recherche future

1. Élaborer des spécifications fondées sur les normes prescriptives susmentionnées.

2. Effectuer les travaux de rénovation selon les recommandations formulées dans le présent rapport. Enregistrer les frais réels. Effectuer une deuxième évaluation de la qualité de l'air intérieur et de l'efficacité énergétique dans chaque maison après la rénovation. Analyser les données pour connaître le degré de réussite atteint et toute lacune présente dans les méthodes d'évaluation, les estimations de coûts ou l'exécution des travaux conformément aux spécifications. Formuler des recommandations visant à assurer la réussite des futurs travaux de rénovation.

3. Comparer les fonds affectés à l'habitation dans une collectivité pour une période donnée à l'état des logements produits ou rénovés grâce à ces dépenses. Établir les réussites ou les échecs à cet égard. Formuler des recommandations pour que les dépenses futures soient plus efficientes.

Conclusions

Dans ce petit échantillon, la maison construite en 1999 n'est pas plus durable et n'offre pas une meilleure qualité de l'air que les maisons bâties entre 1970 et 1990.

Les maisons n'ont pas été construites conformément aux normes reconnues à l'échelle nationale, sans compter qu'elles ne sont pas achevées. Il est recommandé de construire selon les normes prescriptives du Code national du bâtiment du Canada (1995) et du Code modèle national de l'énergie pour les habitation (1997).

En appliquant le protocole d'investigation sur la qualité de l'air intérieur de la SCHL, le système d'évaluation des maisons ÉnerGuide et une liste de vérification basée sur les normes prescriptives susmentionnées, les fournisseurs de services techniques des Premières nations pourront formuler des recommandations concernant les maisons existantes et la construction de maisons neuves. Comme de nombreuses défaillances se rapportent à la sécurité, à la durabilité, au drainage et à la réparation de dommages, les économies d'énergie estimatives ne permettraient pas de récupérer l'argent engagé pour toutes les rénovations requises à l'intérieur d'une période de temps raisonnable. Toutefois, une réduction des frais d'énergie contribuerait à compenser les dépenses en immobilisations qu'il faudrait engager. Les maisons rénovées dureraient plus longtemps, seraient plus confortables et offriraient une meilleure qualité de l'air intérieur.

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Chapter 1: Introduction

The Problem

First Nations communities have some of the worst housing conditions in Canada. The majority of households are in houses falling below at least one housing standard. Climatic extremes, poor construction, crowding, and lack of sufficient resources to undertake continuing maintenance contribute to rapid housing deterioration, resulting in much of the housing being in need of major repair despite being relatively new[1].

Poor building durability is accompanied by poor indoor air quality (IAQ) and high energy costs. IAQ investigations of First Nations housing performed according to the CMHC IAQ Investigative Protocol often result in recommendations that would increase building durability and energy efficiency (EE) as well as improve indoor air quality[2]. The capital costs of implementing these recommendations versus the projected long-term savings have never been measured. Financial and social cost savings associated with improved indoor air quality are difficult to quantify with hard data. Projected savings due to improved durability are also hard to measure. However, using recognized protocols, energy consumption of existing houses can be modeled and can be compared to the estimated energy consumption of proposed renovations or new housing.

Recommendations resulting from an IAQ investigation performed according to the CMHC IAQ Investigative Protocol could be combined with recommendations from an energy audit much like an Energuide for Houses Evaluation. The cost of implementing the recommendations could be compared to the projected energy cost savings.

Will these combined recommendations for affordable renovations or new construction prove to be cost-effective?

Methodology

Conduct IAQ investigations and EE evaluations, according to the recognized protocols noted above, on five sample houses volunteered by the Washagamis Bay First Nation, assisted by a community member with housing responsibilities and an interest in inspection training.

Estimate the capital costs associated with implementing affordable recommendations.

Link the resulting IAQ and energy saving recommendations together.

Compare the house improvement recommendations, capital costs, estimated energy consumption and expected capital cost payback projections.

Deliver the final report both to CMHC and, through a ½ day presentation, to the Washagamis Bay First Nation and other interested communities in the Kenora area.

Chapter 2: House Investigation Number One

Figure 1: House 1 exterior, southeast corner

The Occupant's Perspective

The band owns this house. The present occupants, a woman, age 24, and a girl, age 7, moved in during the spring of 1998. A man, age 27, works away but lives here on weekends. The woman occupant of this house believes that the "house is rotting". She notes a musty odour when she enters the home. There are no apparent problems with water penetration or flooding.

In 1999, new flooring, walls, tub, toilet and sink were installed in the bathroom that previously had suffered mold and mushroom growth and floor rot. The west side bedroom is cold in winter. During the heating season, water condenses frequently on the windowpanes in all rooms. There is also frequent condensation on the floors.

A window air conditioner is used in summer. Windows are opened occasionally for ventilation but none of them have screens. There is a broken window in the east bedroom.

The pellet stove is not used. When an attempt was made to use it the carbon monoxide alarm sounded. The electric heaters make the house "too dry". The living room heater doesn't work and the bathroom heater is detached from the wall. The kitchen oven is used for heating.

People sometimes, but not always, remove their shoes when entering. There is no vacuum cleaner. Pest problems include mice, ants and spiders.

Two people who live here smoke in the house. The woman suffers from constant colds. She reports feeling better when she is away from the house.

Site Observations May 15, 2000

Weather
Clear, sunny, calm, temperature (T) 14C, relative humidity (RH) 62%
Dry ground conditions

Limitations to the investigation
None

Exterior
Detached bungalow about 10 years old
Sloping grade toward house on the north side
Settled grade adjacent to foundation
Both porches missing boards – unsafe
Scattered debris
Good sun exposure and airflow
Bathroom fan exhaust hood on roof
No air intakes
Wood frame construction with wood siding
Original windows – unpainted wood frame horizontal sliders, double glazed, no screens, broken pane in northeast bedroom
Doors – insulated steel, no trim or airseal on inside of doorframe
All caulking in poor condition
Wood soffits and fascia
No eavestroughs or downspouts
Medium slope roof, asphalt shingles, good condition
Interior prefabricated metal chimney with cap – not used – woodstove taken out, sidewall vented pellet stove installed

Attic
Attic access through large hole in poly in northeast bedroom closet
Large holes in poly air/vapour barrier in living room around fan/light
Ceiling insulation – R20 plus R12 glass fibre batts = R32
Airspace between insulation and roof deck at eaves but not at every truss

Foundation
T 15C; RH 60%
Preserved wood crawl space foundation on concrete footing
Footing exposed at grade level on south side
Ventilated to outside in some seasons – 2 south vents, closed; none on other sides
Heated in some seasons – portable electric heater on floor
Ill-fitting plywood access door, south side
Earth floor – no moisture barrier
Some mold on debris
White, wispy mold on soil
No floor insulation, drain, or sump pit
Evidence of repaired bathroom plumbing leak
Plumbing drain, waste and venting (DWV) not well supported
Wall insulation – R20 glass fibre batts – some missing
Wall 6mil poly air/vapour barrier, not continuous – hanging, unsealed
Floor joists – 2x8 with plywood subfloor
No rim joist insulation or airsealing
Some storage – old glass fibre batts, rags, planks, old plumbing line

Mechanical Systems
All mechanical equipment main floor
Baseboard electric heat, living room not working, bathroom detached from wall
Centrally located Envirofire Model EF-II pellet stove, clean, sidewall vented (probable cause of smoking incident – not adjusted – hopper dropped too many pellets – occupant not knowledgeable in stove operation), venting within 4 feet of window
Combustion air supply from indoors
No make-up air supply
Domestic hot water (DHW) Giant 40 gallon, "Double Glass" Model 152E-A-3, 3,800 watts each element
No laundry equipment
No vacuum

Main Level Building Envelope
Main walls 2x6 @ 16" on centre, R20 glass fibre batt insulation, waferboard sheathing assumed, wood siding
Windows double glazed, clear, air fill, horizontal sliders
Doors steel, polyurethane core assumed
Airchange rate at 50 pascal pressure difference = 6.81 airchanges per hour

Kitchen
T 17C, RH 62%
Slight musty odour
Floor vinyl composition tile, fair condition, poor under refrigerator
Walls painted hardboard panels, fair condition
Ceiling painted ceiling tiles, water stain southeast corner
Unpainted window frames, some water stains
Wet, moldy under sink – leak not apparent
Electric baseboard heating (attached thermostat) plus use of oven
No ventilation
Bugs in pail of water under sink
Mouse feces under sink
Large open garbage storage

Bathroom
T 17C, RH 62%
Vinyl sheet flooring, good condition
Painted drywall ceiling, good condition
Painted drywall walls, poor condition, hole in east wall, deterioration at head of tub adjacent to toilet
No window, tub against exterior wall
No visible plumbing leaks
Lined toilet tank (1.6 gpm flush)
Electric heater, attached thermostat – detached from wall
Ceiling exhaust fan, dirty, clogged, controlled by switch, flow measurement 15 cfm
Typical cleaning chemicals, air freshener

Northwest bedroom
Vinyl tile floor, good condition
Painted ceiling tile, poor condition, many holes, water stains
Painted hardboard panel walls
Unfinished wood windows, some water stains, fair condition
Moderate closet storage on floor, no closet rod, no door
Electric baseboard heat, attached thermostat

Northeast bedroom
Vinyl tile floor, good condition
Painted ceiling tile, waterstains at edge
Painted hardboard panel walls, fair condition
Unfinished wood slider window, slight water stain, inside pane broken (safety hazard)
Closet –no rod – gaping hole in ceiling air/vapour barrier –used as attic access
Electric baseboard heat, attached thermostat

Living room
Vinyl tile floor, area rug
Painted hardboard panel walls
Painted ceiling tile, missing tiles, poor air/vapour barrier, big hole around fan/light
Windows - top fixed with bottom slider, cracked pane southeast slider
Pellet stove
Floor deteriorated in hall adjacent to bathroom

Indoor Air Quality Recommendations

Recommendations to improve indoor air quality are offered for each house. These recommendations are divided into measures that can be done easily at no or low cost, measures that are of medium cost and finally some measures that are of higher cost. In each category, the recommendations are listed in approximate order of their indoor air quality significance. **Some recommendations that serve similar purposes may be found in two or three categories. They are offered as options.** The differences between them are largely based on cost and effectiveness. For example, repairing a broken bathroom exhaust fan, upgrading to a more effective fan and installing a heat recovery ventilator which exhausts air from the bathroom all serve a similar purpose but the cost and effectiveness of each is different.

Although not the focus of this investigation, some safety concerns were noted. The pellet stove venting does not meet the manufacturer's requirements (see medium cost #1). Some of the electrical installations require repair (see lower cost #12). Both decks are rotten and should be replaced. The inside pane on the child's bedroom window is broken and should be replaced.

Lower Cost Recommendations

1. **Discourage smoking in the house.** Smoking by anyone, in any room, will

result in second-hand smoke dispersing throughout the house, affecting all occupants. The effects of environmental tobacco smoke are well documented.

2. **Clean up small areas of mold.** There is a small amount of mold in the cabinet under the kitchen sink. Wear rubber gloves, glasses or safety goggles, a dust mask and a shirt with long sleeves. Throw out wet and badly damaged or musty smelling materials. For washable surfaces, scrub with a detergent solution; then sponge with a clean wet rag and dry thoroughly. Although there wasn't an apparent plumbing leak under the sink, find the source of the water and eliminate it. Otherwise the mold will return. Look for mold throughout the house. If you find any small areas of mold on drywall, clean the surface with a damp rag using baking soda or a bit of detergent. Do not allow the drywall to get too wet.

3. **Conduct a thorough 'spring cleaning'.** A whole house cleanup, including washing blankets and area rugs, can reduce dust and food for molds. Get rid of clothes or stored items that are not used. Vacuum the house thoroughly with a vacuum cleaner equipped with a high efficiency particulate arresting (HEPA) filter (see medium cost #13). All surfaces in the house (floors, walls, ceilings, shelves) and non-washable furnishings (sofas, chairs, etc.) must be vacuumed thoroughly. Vacuuming removes settled dust that may contain an accumulation over time of mold spores. Reducing the settled dust reduces molds. HEPA vacuuming and damp wiping surfaces is the best way to prevent mold spores and contaminants from mice feces from becoming airborne. Keep all rooms and closets tidy to make it easier to circulate air and provide less opportunity for dust mites and molds to grow. Keep garbage in a covered container that is emptied daily. Protected outside garbage storage is essential.

4. **Set spring-loaded mousetraps in the house continuously.** Use gloves when handling dead mice. Put dead mice in plastic bags and dispose of them promptly. Use steel wool or cement to seal, screen, or cover all openings into the home that are larger than .5 cm (1/4 inch). Keep food and water covered and stored in rodent-proof metal or thick plastic containers with tight fitting lids. Wash dishes and cooking utensils immediately after use. Remove all spilled food promptly. Outside, reduce rodent shelter and food sources near the house by hauling away trash or anything that may serve as a rodent nesting site. Cut grass and brush near the house.

5. **Clean the debris out of the crawl space.** Debris includes plastic bags, a laundry hamper, rags, boards, pipes, screen and pieces of glass fibre insulation on the dirt floor.

6. **Check the refrigerator defrost drip pan or line for water leaks.** There are water stains on the floor under the refrigerator. Eliminate the source of the water. Clean the refrigerator drip pan regularly with dish detergent and water to minimize mold growth.

7. **Inventory the cleaning chemicals in the house and discard those that are not necessary.** Minimize the use of air fresheners and cleaning chemicals. Unscented dish detergent, baking soda and water, or vinegar and water are some of the alternative cleaners that can be used to reduce the chemicals in the house.

8. **Clean the bathroom exhaust fan.** The clogged fan only allows a very low flow of about 15 cubic feet per minute (cfm). A dust-free fan will allow better airflow. Use the bathroom fan frequently.

9. **Move the child's bed away from the electrical panel.** There is an electromagnetic force field around the electrical panel. There is much debate

over acceptable levels of exposure to such fields. However, it is known that the force fields drop off quickly with distance from electrical devices. Avoid locating beds near electrical devices, such as the panel, just as a matter of caution.

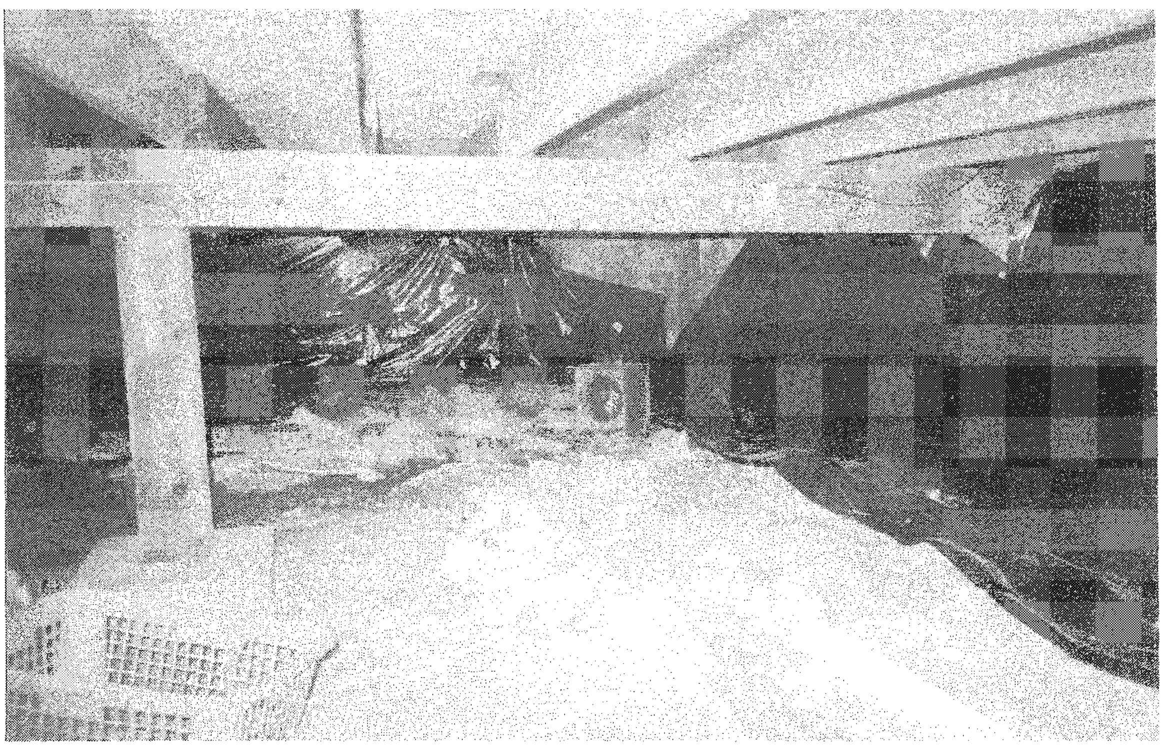
10. **Install a plastic dam at the head of the tub.** These small self-adhesive plastic dams can be fastened to the rim of the tub against the wall and help (slightly) to reduce leaks over the edge of the tub during showers.

11. **Encourage another knowledgeable community member to train the home occupants in the use of the pellet stove.** This will not only reduce the possibility of backdrafting, as happened previously, but will also enable the occupant to heat mainly with lower cost pellets rather than electricity. Continue to use the electric heaters in the bedrooms, bathroom and crawl space.

12. **As a safety measure, as well as to provide warmer surfaces to prevent mold growth, repair the electric heaters in the bathroom and living room and ensure that they are firmly attached to the wall.** As well, fix all light fixtures to the ceiling and install switch and receptacle cover plates where needed. Set the east side outside receptacle into the wall and ensure that it is weatherproof.

13. **Install more hangers on the drain, waste and vent (dwv) plumbing lines in the crawl space.** The lines are poorly supported. To avoid sags or strain, install more hangers.

Figure 2: House 1, crawl space, no floor moisture barrier, poor air/vapour barrier, debris



Medium Cost Recommendations

1. **Relocate the pellet stove sidewall vent termination not less than four feet horizontally from the window.** The installation manual for the Envirofire EF-II pellet stove requires that the vent termination must be not less than 4 feet (1.2 m) below, not less than 4 feet (1.2 m) horizontally from, and not less than 1 foot (305 mm) above any door, window or ventilation air inlet into the building. The current installation is about 6 inches below and 30 inches horizontally from an operable horizontal slider window. The safest and preferred method is to extend the vent through the roof[3].

2. **Install a sealed moisture barrier over the crawl space dirt floor.** Even out any dips in the floor. Lay sheets of 6mil or preferably thicker polyethylene, tough enough to resist tears, over the whole floor. Overlap and seal joints with caulking or sheathing tape. Adjacent to each wooden floor beam support post, temporarily jack up the main beam slightly. Slip a sheet of poly between the bottom of the wood post and the concrete footing. If this is not possible, at least seal the main sheets of poly to the edges of the post footings. (Do not seal the poly to the wood post, which could cause the bottom of the post to rot faster). At the edges of the floor, ensure that the poly extends up and over the concrete footing to the preserved wood framing. Seal it to the bottom plate of the preserved wood framing. A sealed floor moisture barrier is an important step in reducing moisture in the crawl space as well as in the rest of the house. Set the existing electric construction heater on a level concrete patio slab.

3. **Install a sealed polyethylene air/vapour barrier at the penetrations on the ceiling in the living room and in the child's bedroom closet.** Remove the chimney that is no longer in use (or, if it is appropriate, use it to vent the pellet stove). Ensuring that the air/vapour barrier is sealed will reduce air and moisture leakage into the attic and also reduce exposure to the glass fibre insulation. (See medium cost #15).

4. **Re-install the existing poly on the crawl space walls.** Remove the existing poly. Discard any wet glass fibre batts. Note any foundation leaks that may be corrected from the outside. Remove the crawl space vents and seal the openings. Ensure that the preserved wood frame walls are dry and fully re-insulated with dry glass fibre batts. Re-install a 6 mil poly air/vapour barrier on the inside face of the crawl space walls, ensuring that all joints are overlapped and sealed with sheathing tape. Seal the top edge to the top plate of the preserved wood framing. A continuous wood furring strip along the top edge can help to ensure an airtight seal. Note: moisture from the ground will still wick up through the concrete footing and into the preserved wood framing. PWF foundation walls should never be built on concrete footings without some type of capillary break between the concrete and the wood. Drainage is important to keep the foundation as dry as possible. An interior sealed wall air/vapour barrier is needed to make the best of a bad situation.

5. **Undercut the room doors to leave at least a 25mm (1 inch) gap.** The pellet stove, which has a 45 cfm exhaust blower, and the current bathroom fan (at about 15 cfm) provide some exhaust ventilation. Undercutting doors will provide more opportunity for building air leakage to circulate air throughout the house.

6. **Replace the current bathroom fan with a better quality, quieter fan that would likely be run more often (such as the Panasonic WhisperCeiling FV-07VQ2).** Install smooth-walled metal duct with sealed joints in the shortest, most direct route from the fan to the outside of the house. Insulate the duct through the attic.

Control the fan with an electronic timer that can be set to run for long periods.

7. **Replace the current crawl space access door.** Install a tight-fitting pwf door complete with two two-inch layers of extruded polystyrene (with protective cover) on the inside and weather-stripping on all four edges.

8. **Install blocks of two inch extruded polystyrene around the perimeter of the floor framing, between the floor joists.** Seal around all four edges of each block with solvent-free silicone sealant. Cover with a fire-resistant material required according to sentence 9.10.16.10. National Building Code of Canada 1995[4]. For the cover, use a gypsum board faced with inorganic glass mats front and back (such as 5/8" Dens-Glass Gold Fireguard from Georgia Pacific Ltd) or a cement board (such as Durock from Canadian Gypsum Company). Do not cover with regular paper-faced gypsum board that will support mold growth more readily.

9. **Monitor the condition of the crawl space.** With sealed poly on the floor and walls and better drainage, natural air movement from the crawl space to the main living area through any existing holes should keep the crawl space dry. Only if necessary, install a foundation exhaust fan to slightly depressurize the crawl space.

10. **Airseal the main living area.** Air leaks were discovered around the doors, windows, electrical receptacles, light switches, behind the baseboard along the bottom edge of the exterior walls, around plumbing vents and through the living room and bedroom ceiling where the poly was torn or missing. New sections of poly, gaskets, caulking and weather-stripping can be used to tighten up these penetrations. Do not seal the numerous plumbing and electrical penetrations through to the crawl space, which must be considered as part of the conditioned space of the house.

11. **Install screens on the operable windows.** Natural ventilation through open windows could provide some fresh air in the spring, summer and fall.

12. **Install eavestroughs and downspout extensions to direct water away from the foundation.**

13. **Purchase and regularly use a portable HEPA vacuum cleaner.**

14. **Replace the damaged floor finish in the hall outside the bathroom and under the refrigerator.** Replace the damaged ceiling tiles and repair any holes in the walls, to enable easier cleaning.

15. **Install a gable end attic access door to enable attic access from the outside.**

16. **Install polystyrene or cardboard insulation deflectors between each roof truss at the eaves, to allow better airflow from the soffits over the insulation to the attic.** Ensure that the attic insulation extends right to the outside edge of the wall framing.

17. **Install closet rods and shelves.** Clothing storage on the floor against outside walls can lead to cold spots, condensation and mold growth in hidden corners.

Higher Cost Recommendations

1. **Install a perimeter drain tile beside the footing, complete with at least 150 mm (6 in) of crushed stone and a filter cloth.** Since there is no drainage layer under the foundation, a perimeter drain tile is needed. Excavate the north, east and west sides down to the bottom of the footing. Provide a discharge line that runs out of the south hillside below the level of the footing.

2. **Damp-proof and backfill the foundation**. Clean the dirt off the plywood wall and concrete footing. Caulk all joints in the plywood sheathing. Install 6 mil polyethylene sheeting or equivalent coating (or both) from about 75 mm (3 in) above the finished grade level to the bottom of the footing. Seal the top edge of the poly to the plywood wall all along its length. Protect the top edge of the poly with a 300 mm (12 inch) wide, 13 mm (1/2 in) thick, treated plywood cover strip. This cover strip could extend to the bottom of the siding where it would be protected from rain penetration by a metal flashing extending up under the siding. Protect the below grade corners with vertical plywood cover strips.

   This is also an ideal opportunity to install at least a 600 mm (2 feet) wide horizontal strip of 63 mm (2 1/2 in) Type 2 expanded polystyrene insulation over the footing, with a slight slope away from the building. In this climate, a 1.2 m (4 feet) wide insulation skirt would be preferred.

   Since the surrounding soil seems relatively free draining, it can be used for backfill. Backfill to no higher than 200 mm (8 inches) below the level of the siding, making adjustment for the crawl space access door and any foundation vent fan. Ensure that the finished grade slopes away from the building on all sides.

3. **Re-finish the exterior to better protect the building.** Re-finish the siding and window frames. Caulk around all windows and doors. Replace the plywood soffits with vented aluminium. Cover the existing wood fascia with aluminium.

In conclusion, it must be noted that this house is not really in bad shape yet. With the maintenance and renovations suggested above, it could provide the occupants with good housing for many years.

Energy Efficiency Recommendations

Table 2.1: House 1 Potential Energy Efficiency Upgrades			
This table illustrates some of the potential upgrades. Annual energy costs have been estimated with the HOT 2000[5] computer software.			
Options	**Particulars**	**Estimated annual energy cost**	**Savings from current cost**
This house	Air change rate: 6.81 airchanges per hour @ 50Pa pressure difference (.344 average annual natural airchange rate); building as is; no continuous mechanical ventilation	$2,474	
This house ventilated	Current house with 17 cfm mechanical ventilation + .344 natural airchange = total airchange of this house airsealed to 3.57 ac/h @ 50 Pa & continuously ventilated at 30 cfm	$2,528	Plus $54
This house heated with wood pellets	Train the home occupants in the use of the pellet stove – assume 75% of space heating wood pellets; not including capital cost of pellet stove (already installed) Annual maintenance is required; add $70	$2,202 $2,272	$272 $202
Code house	This house if built to building envelope specifications of the MNECCH 1997[6] with 30 cfm continuous heat recovery ventilation, electric heat, no wood pellet stove	$1,848	$626
Upgrade 1	Airsealing to 3.57 airchanges per hour = usual new house	$2,320	$154
Upgrade 2	Airsealing to 3.57 ac/h; add R10 main floor perimeter	$2,294	$180
Upgrade 3	Airsealing to 3.57 ac/h; R10 footing insulation 2 feet wide	$2,243	$231
Upgrade 4	Airsealing to 3.57 ac/h; R10 floor perimeter insulation; R10 footing insulation 2 feet wide	$2,206	$268
Upgrade 5	Airsealing to 3.57 ac/h; R10 floor perimeter insulation; R10 footing insulation 2 feet wide; use wood pellet stove for 75% of space heating; (plus install quiet bathroom fan used intermittently – no energy efficiency effect calculated) Annual stove maintenance is required; add $70.	$2,013 $2,083	$461 $391

Table 2.2 House 1 Estimated Upgrade Costs and Payback			
Upgrade	**What is included (referred to IAQ recommendation #s)**	**Estimated Cost**	**Annual Energy Cost Payback**
Pellet stove training	L11 Training by knowledgeable community member	Labour one hour $20 (Include annual pellet stove maintenance of $70 = $202 saving)	$20 cost / $202 saving = 5 week payback
Renovating to code	Full crawl space floor insulation (R9), insulating sheathing and new siding (total R27), R 60 ceiling insulation, heat recovery ventilation	Floor insulation $1,600 Sheathing and siding $6,000 Ceiling insulation $800 Heat recovery ventilation $1,800 Airsealing $870 Total $11,070 (plus other associated costs below)	$11,070 / $626 = 17.7 years minimum
1. Airsealing to 3.57 ac/h @ 50 Pa.	M2 Sealed air/moisture barrier on crawl space floor	1,000 sq.ft. 6 mil poly $56 1 roll sheathing tape $18 Caulking $30 Labour 4 hours @ $20 $80	
	M3 Sealed ceiling air/vapour barrier (no chimney removal – may be used)	Poly, caulking, tape $30 Labour $40	
	M4 Re-insulate and airseal crawl space walls (assume glass fibre insulation ok)	500 sq.ft. 6 mil poly $28 1 roll sheathing tape $18 Caulking $30 Labour 4 hours $80	
	M5 Replace crawl space access door	PWF plywood piece $15 Extruded polystyrene $10 Weatherstrip, latch $15 Labour 2 hours $40	
	M6 Seal perimeter of floor framing	Silicone caulking $60 Labour 3 hours $60	
	M8 Airseal the main living area	Caulking, foam, gaskets, tape$100 Labour 8 hours $160	
	Total airsealing costs	$870	$870 / $154 = 5.6 years
2. Airsealing plus main floor perimeter insulation	Airsealing M6 R10 extruded polystyrene (XTPS)+ cover at floor perimeter between joists	$870 XTPS + cover $120 Sealing already counted Labour 10 hours $200 Total $1190	$1190 / $180 = 6.6 years
4. Airsealing, floor perimeter insulation, footing insulation	Airsealing Floor perimeter H1 Footing insulation (no excavation, backfill, drainage – all needed anyway)	$870 $320 15 sheets R10 EPS 2 $186 Labour 6 hours $120 Total $1496	$1496 / $268 = 5.6 years

5. Airsealing, R10 floor perimeter, R10 footing insulation, 75% wood pellet heating, new bath fan	Airsealing Floor perimeter Footing insulation Door undercuts & bath fan Wood pellet stove training	$870 $320 $306 $400 $20 Total $1916	$1916 / $461 = 4.2 years
6. As in 5 with annual stove maintenance	5. Stove maintenance	$1916 $70 Total $1986	$1986 / $391 = 5.1 years

Energy Efficiency Recommendations Commentary[7]

Using the existing wood pellet stove, rather than electric baseboards, for about 75% of the space heating, would result in a saving of $202 (after maintenance costs are included) in the current house and a payback on the training cost in a little over 5 weeks. If the house were renovated to upgrade option #4 or #5, less space heating would be required so the annual saving attributable to using wood pellets is estimated at $123.

For safety and efficiency, the stove should be checked and maintained according to the manufacturer's instructions. A typical annual wood stove and chimney maintenance check costs about $70.

Since the stove is already in place, the capital cost of the installation has not been included in the cost calculations. According to the Ontario distributor, the average installed cost of this model would be about $2,300. If that cost were considered, the apparent annual saving of $202 in the current house would take 11.4 years to recoup.

In the renovated house, at an annual saving of $123, the capital cost would take 18.7 years to recover. Handling costs and provision of dry storage space for pellets are not included.

To realize the above savings using the wood pellet stove, the occupant will have to process from 80 to 120 bags (40 lbs. each) of pellets per year. Not all home occupants may be able to do this.

The current pellet stove vent installation does not meet the manufacturer's requirements. Retrofitting the venting will add more cost.

This stove is power vented with a 45 cfm fan[8] that runs at a constant rate whenever the stove is operating. The stove also has a convection fan for heat distribution and an auger motor to draw pellets from the hopper, for a total electrical usage of 240 watts. A conservative estimate of 3,000 hours of operation (1/3 of the year) would result in a pellet stove electricity cost of $57.74. This has been included in the calculations.

The stove uses house air for combustion, so the exhaust blower expels 45 cfm of heated air from the house continuously when in use.[9] This is actually the largest, almost continuous, exhaust appliance in the house.

With little mechanical air circulation, the pellet stove is unlikely to sufficiently heat the bedrooms and bathroom, especially when their doors are closed. Some electric heat is still needed.

Electricity is a costly fuel. However, baseboard heaters are reasonably safe, inexpensive to install and require little occupant effort or expertise to run or maintain.

This house already had a heating system. The money spent on the wood pellet stove installation could have been spent on building envelope energy conservation measures that would have lowered annual energy costs without adding an ongoing burden of effort in loading fuel, maintaining the appliance and providing dry storage for the pellets.

Renovating to MNECCH (Model National Energy Code of Canada for Houses) 1997 now would be more energy efficient but would have a long payback time.

Airsealing to the level of airtightness typical of present day new construction (3.57 ac/h @ 50 Pa) should pay back the money invested in less than six years. With mechanical ventilation provided by a quiet bathroom fan and the exhaust from the pellet stove, these airsealing measures will contribute to the durability of the house so that the annual savings will continue for many years longer than if the house was left in its present condition.

Option 5 seems to be the most realistic way to use the existing resources in the house to provide better indoor air quality and energy efficiency, without adding unnecessary complications. **For safety, the wood pellet stove must first be vented according to the manufacturer's specifications.**

The chart on the following page incorporates:

- indoor air quality recommendations;
- most cost-effective energy efficiency and ventilation recommendations;
- other renovations for durability; and,
- damage repairs;

into one renovation plan.

Table 2.3: House 1 Renovation Plan for Indoor Air Quality, Durability and Energy Efficiency	
No cost / lower cost recommendations	**Cost**
1. Discourage smoking in the house.	
2. Clean up small areas of mold.	
3. Conduct a thorough 'spring cleaning'.	All
4. Set mousetraps continuously.	very
5. Clean the debris out of the crawl space.	low
6. Check the refrigerator defrost drip pan for leaks.	cost
7. Inventory the cleaning chemicals in the house and discard those that are not necessary.	
8. Clean the bathroom exhaust fan (for use until the HRV is installed).	
9. Move the child's bed away from the electrical panel.	
10. Install a plastic dam at the head of the tub.	$10
11. Train the home occupants in the use of the pellet stove.	$20
12. Repair the electric heaters, light fixtures and receptacle cover plates.	$80
13. Install more hangers on the crawl space plumbing drain lines.	$30
Total	**$140**
Medium cost recommendations	
1. Relocate the pellet stove sidewall vent not less than 4 feet from the window.	$200+
2. Install a sealed moisture barrier over the crawl space dirt floor.	$184
3. Install a sealed air/vapour barrier at the ceiling penetrations.	$70
4. Re-insulate and re-install the crawl space wall air/vapour barrier, as required.	$156
5. Replace the crawl space access door.	$80
6. Undercut room doors and install a better bath fan.	$400
7. Insulate and seal the perimeter of the main floor framing.	$520
8. Airseal the main living area.	$260
9. Install screens on some operable windows.	$300
10. Install eavestroughs and downspout extensions.	$320
11. Install a gable end attic access door.	$80
12. Install closet rods and shelves.	$80
Total	**$2,650**
Higher cost recommendations	
1. Excavate and damp-proof the foundation (as described).	$1,200
2. Install foundation perimeter drainage.	$400
3. Install R10 footing insulation 2' wide.	$306
4. Backfill the foundation using surrounding soil and slope grade away from house.	$800
5. Stain the exterior, including soffits, fascia and window frames. Re-caulk around penetrations.	$1,800
6. Replace the back porch and front deck with 2 small porches.	$1,200
Total	**$5,706**
Total indoor air quality, durability and energy efficiency cost	**$8,496**
Interior ceiling, wall and floor damage repairs could cost another $1,500	$1,500
Total cost	**$9,996**
Conclusions Anticipated annual savings from the current house = $391 Renovations capital cost payback period = $9,996 / $391 = 25.6 years Energy savings can only be expected to offset, not completely recover, capital costs. Too many necessary renovations are unrelated to either indoor air quality or energy efficiency. Safety, durability and damage repair are larger issues.	

Chapter 3: House Investigation Number Two

Figure 3: House 2, duplex, left side, southeast view

The Occupant's Perspective

The band owns this house. The house was built in 1998-99 and the present occupants, a man, woman and girl under 12, moved in upon completion in April 1999. There is recurring mold growth on the edges of windows, in the corners of the bedrooms and in the bathroom beside the tub. The occupants clean it frequently but it always returns. There may also be some growth in the crawl space. A minor water leak above the back door was repaired in April of 1999. The occupants plan only minor improvements, including completing the railing on the deck stairs.

The daughter's room, in particular, is cold when the door is closed. Her mother feels that this may be affecting her daughter's health. Water condenses on the bedroom windows frequently. Windows are rarely opened but the bathroom exhaust fan is used regularly.

Typical cleaning products and an in-house dry cleaning chemical are used. Everyone removes shoes upon entering the house. A portable vacuum is used sporadically. The only pests are a few spiders.

Both adults smoke in the house.

Site Observations May 16, 2000

Weather
Clear, sunny, calm, 15C, RH 62%
Dry ground conditions

Limitations to the investigation
None

Exterior
Duplex (subject property west side), approximately one year old

Slight grade from gravel road to south side of house
Good sun exposure and airflow
Foundation never backfilled, footings exposed above grade, footing forms not removed
At times, water drains through the crawl space, under the footing, from south to north
Wood frame construction with vinyl siding
Some siding detached on west side
Bathroom exhaust outlet in south soffit
Pellet stove vent termination within 30 inches directly below operable window
No visible air intakes
Double glazed, extruded vinyl windows, good condition
Insulated steel doors, good condition
Vinyl soffits (vented) and fascia – some fascia missing on north and west sides
No eavestroughs or downspouts
Medium slope roof, asphalt shingles, good condition

Attic
Access door in west gable end
Attic insulated with R40 glass fibre batts
Long, draped, flexible bathroom exhaust duct

Foundation
T 18C, RH 68%
Preserved wood crawl space foundation on concrete footing
Footing exposed above grade on all sides
Crawl space not vented outside
Heated with a 1000 watt electric baseboard heater
Crawl space access hatch in laundry area floor
Dirt floor, no moisture barrier, evidence of a stream of water passing through at times
Pwf walls, 2x6 with R20 glass fibre batt insulation, intended air vapour barrier never installed, still lying on floor
Glass fibre insulation wet in some areas (e.g. northwest corner)
Exterior pwf plywood sheeting, no damp-proofing or backfill
Party wall between units 2x6 pwf framing with drywall both sides, hole large enough to crawl through near laundry area
Visible mold on party wall drywall at north corner, also under leaking plumbing drain (largest) and below heater
Plumbing drain line hangers insufficiently supported
Floor joists – 2 x 10 with plywood subfloor
No floor perimeter insulation or air barrier
Unused drywall, glass fibre batts, poly, abs pipe, cardboard boxes, plywood, plastic pail and other debris on floor, especially under laundry and back entrance

Mechanical systems
Electric water heater, 189.3 litres (42 gal.), located in crawl space, on wood base, element covers never replaced but are laying on floor
Laundry area dryer vented directly into crawl space
Main living area heated with Envirofire EF3 Bayi FS wood pellet stove located in kitchen area, sidewall vented directly under operable window
Smoke detector in hall between bedrooms, no CO detector
Living room ceiling fan and pellet stove fan only means of air circulation
All interior doors undercut less than ½ inch

Main level building envelope
Main walls drywall, 2x6 @ 16" on centre, R20 glass fibre insulation, waferboard sheathing assumed, vinyl siding
Windows vinyl frames, double glazed, low E, argon fill, horizontal sliders
Doors steel, polyurethane core assumed
Ceiling drywall, strapping, trusses, R40 glass fibre batts
Airchange rate at 50 Pascal pressure difference = 2.80 airchanges per hour (crawl space trap door closed)

Kitchen
T 20C, RH 68%
Floor vinyl sheet, good condition
Walls painted drywall, vinyl finish panelling in dining area, good condition
Ceiling painted drywall, good condition
Slight mold on edge of windows
No mechanical ventilation
Large open indoor garbage storage

Bathroom
T 20C, RH 68%
Floor vinyl sheet, good condition

Wall, painted drywall, good condition except at head of tub where water leaks from showers onto wall and floor behind toilet – black mold
No window
Bathroom exhaust fan, controlled by switch, approximately 25 cfm airflow

Laundry/back entry area
Slight mold in outside corners
Major air leak around rear door
Plug-in air freshener

Master bedroom
T 20C, RH 67%
Floor vinyl sheet, good condition
Walls and ceiling painted drywall, good condition
Condensation and slight mold on edge of window
Slight mold growth on wall, lower northwest corner behind bed, also in closet at upper outside corner

Second bedroom
T 19C, RH 67%
Floor vinyl sheet, good condition
Walls and ceiling painted drywall, good condition
Condensation and slight mold on edge of window
Slight mold growth on wall at northeast corner behind bed
Hall linen closet has large hole in ceiling air/vapour barrier

Living room
T 19C, RH 67%
Floor vinyl sheet, good condition, area rug
Walls and ceiling painted drywall, good condition
Condensation and slight mold on edge of windows
Some candles, not used often
One plant, dead leaves on soil

Indoor Air Quality Recommendations

These recommendations are divided into measures that can be done easily at no or low cost, measures that are of medium cost and finally some measures that are of higher cost. In each category, the recommendations are listed in approximate order of their indoor air quality significance. Some recommendations that serve similar purposes may be found in two or three categories. They are offered as options.

Although not the focus of this investigation, some safety concerns were noted. The pellet stove venting does not meet the manufacturer's requirements (see medium cost #1). There is no carbon monoxide detector. The fire separation between the two units in the crawl space is not continuous from the footing to the underside of the main floor. This wall also has a large hole in it near the laundry area. The back deck railing should be completed. Finally, the large wasp nest on the west side of the building should be carefully removed.

Lower Cost Recommendations

1. **Install a carbon monoxide detector in the main living area.**

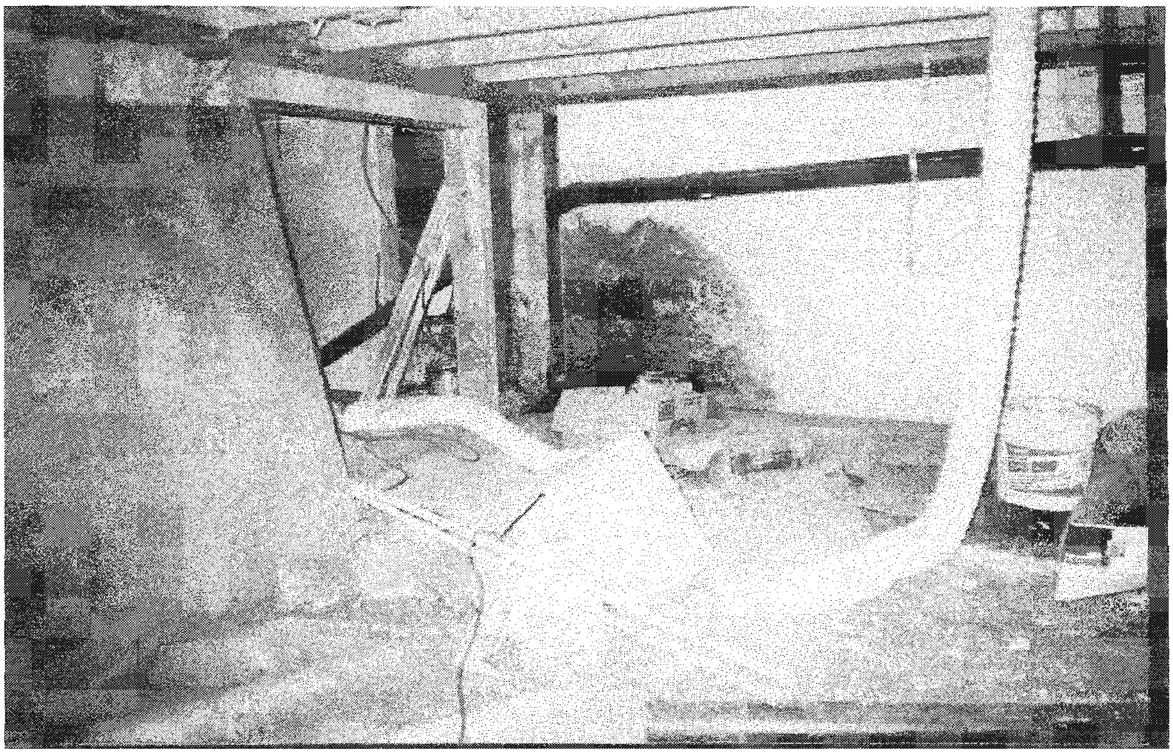
2. **Discourage smoking in the house.** Smoking by anyone, in any room, will result in second-hand smoke dispersing throughout the house, affecting all occupants. The effects of environmental tobacco smoke are well documented.

3. **Continue to clean up small areas of mold.** Small amounts of mold were noted along the edges of the windows, on the exterior walls of the bedrooms behind the beds, on the upper corner of the exterior wall of the master bedroom closet, on the bathroom wall behind the toilet and on the exterior wall corners in the back entry. Wear rubber gloves, glasses or safety goggles, a dust mask and a shirt with long sleeves. Throw out wet and badly damaged or musty smelling materials. For washable surfaces, scrub with a detergent solution; then sponge with a clean wet rag and dry thoroughly. Look for mold throughout the house. If you find any small areas of mold on drywall, clean the

surface with a damp rag using baking soda or a bit of detergent. Do not allow the drywall to get too wet. (See medium cost #2.)

4. **Fix the leak in the plumbing drain line in the crawl space.** The main plumbing drain line is leaking at a joint. The leak is located on the line between all of the plumbing fixtures and the septic tank, at the northeast corner of the party wall under the laundry room. This leak, which has probably existed since the house was built, is a continuing source of contaminated water that wets the party wall drywall. This has caused an area of mold growth on the drywall that is approximately 2 feet x 3 feet. Ensure that all drain lines are well supported. (See medium cost #2.)

Figure 4: House 2 crawl space, plumbing leak, mold



5. **Replace the looping, flexible plastic bathroom exhaust duct in the attic.** Install a horizontal, insulated metal duct with sealed joints, in the shortest, straightest route to the exterior possible, sloped to the outside and terminating clear of the soffit. Run the bathroom exhaust fan frequently to exhaust some of the excessive humidity in the house.

6. **Vent the dryer outside.** For as much of its length as possible, change the dryer ducting to smooth-walled aluminium duct with sealed joints, installed in the shortest, straightest route possible to a dryer vent hood on the exterior of the building.

7. **Clean the debris out of the crawl space.** This includes the unused drywall scraps, glass fibre batts, poly, ABS pipe, cardboard boxes, plywood, the plastic pail of dirty water and so on. It would be best to remove a sheet of the crawl space wall plywood and use the opening as a temporary access hatch, to minimize dust and mold spores distributed on the main floor. (See medium cost #2.)

8. **Inventory the cleaning chemicals in the house and discard those that are not necessary.** Minimize the use of air fresheners and cleaning chemicals, including the home dry cleaning chemicals and scented or solvent-based (nail polish remover) personal care products. Unscented dish detergent, baking soda and water, or vinegar and water are some of the alternative cleaners that can be used to reduce the chemical loading in the house.

9. **Keep kitchen garbage in a smaller, covered, container that is emptied daily.** Protected outside garbage storage is essential.

10. **Install a plastic dam at the head of the tub.** These small, self-adhesive plastic dams can be fastened to the rim of tub and help (slightly) to reduce leaks over the edge of the tub during showers.

11. **Leave the interior room doors open as much as possible**, to encourage better air circulation. Undercut the bottoms of the doors to leave at least a 1inch gap under each door to encourage more air circulation when they are closed (this will not work well without any forced air supply or exhaust to the rooms, see higher cost #2).

12. **Remove the dead leaves from the plant pots.** Any plants should be kept in plastic pots with the soil watered only as necessary but not kept soaking wet. Remove any dead leaves frequently. Cover the soil with a layer of stones.

Medium Cost Recommendations

1. **Relocate the pellet stove sidewall vent termination not less than four feet horizontally from the window.** The installation manual for the Envirofire pellet stove requires that the vent termination must be not less than 4 feet (1.2 m) below, not less than 4 feet (1.2 m) horizontally from, and not less than 1 foot (305 mm) above any door, window or ventilation air inlet into the building. The current installation is about 30 inches directly below an operable horizontal slider window. The safest and preferred method is to extend the vent through the roof.

2. **Discard the moldy drywall in the crawl space.** Remove a sheet of the exterior foundation wall plywood and use this as a temporary access hatch. Keep the main floor access hatch closed. At the very least, wear rubber gloves, safety goggles, a half face respirator with HEPA cartridges, and a disposable Tyvek suit. With sheathing tape and 6mil poly, cover the moldy drywall. Cut out and remove the covered, moldy drywall well beyond (preferably 1 metre) the affected area. Double bag the discarded drywall in garbage bags and dispose of it in the dump.

   Note:
   "In a *building of residential occupancy* in which there is no *dwelling unit* above another *dwelling unit*, a *party wall* on a property line between *dwelling units* need not be constructed as a *firewall* provided it is constructed as a *fire separation* having not less than a 1 hour *fire-resistance rating*." National Building Code of Canada (NBCC) 1995, Sentence 9.10.11.2.1.

   "The wall described in sentence (1) shall provide continuous protection from the top of the footings to the underside of the roof deck." NBCC 1995, Sentence 9.10.11.2.2[10].

   The fire separation between units must be maintained. (See higher cost #2.)

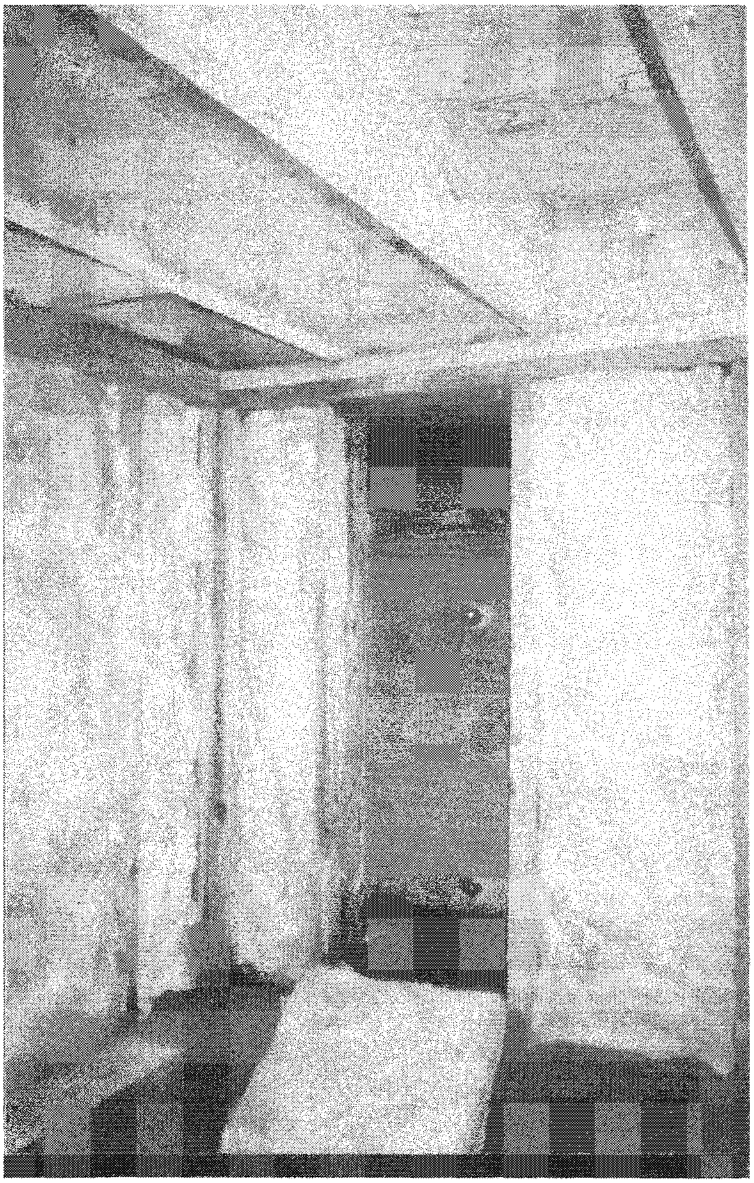
3. **Remove the footing forms and install a perimeter drain tile beside the footing,** complete with at least 150 mm (6 in) of crushed stone and a filter cloth. Provide a discharge line that runs out of the north hillside below the level of the footing. These footings are wet and are 'wicking'

water up into the pwf frame wall. Drainage will help but will not cure this problem. Ideally, this recommendation would form part of an overall drainage, damp-proofing, footing insulation, backfilling and grading installation (see higher cost #1).

4. **Install a sealed moisture barrier over the crawl space dirt floor.** Even out the floor grade. Lay sheets of 6mil or preferably thicker polyethylene, tough enough to resist tears, over the whole floor. Overlap and seal joints with caulking or sheathing tape. Seal the main sheets of poly to the edges of the post footings. At the edges of the floor, ensure that the poly extends up and over the concrete footing to the preserved wood framing. Seal it to the bottom plate of the preserved wood framing. A sealed floor moisture barrier is an important step in reducing moisture in the crawl space as well as in the rest of the house

5. **Remove the existing glass fibre batt insulation from the crawl space walls.** Discard any wet glass fibre batts. Note any foundation leaks that may be corrected from the outside. Ensure that the preserved wood frame walls are dry and fully re-insulated with dry glass fibre batts. Install a 6mil poly air/vapour barrier on the inside face of the crawl space walls, ensuring that all joints are overlapped and sealed with sheathing tape. Seal the top edge to the top plate of the preserved wood framing. A continuous wood furring strip along the top edge can help to ensure an airtight seal. Note: moisture from the ground will still wick up through the concrete footing and into the preserved wood framing. PWF foundation walls should never be built on concrete footings without some type of capillary break between the concrete and the wood. Drainage is important to keep the foundation as dry as possible. An interior sealed wall air/vapour barrier is needed to make the best of a bad situation.

Figure 5: House 2 foundation walls and insulation wet from capillary action and condensation



6. **Install an air exchanger ventilation air mixing box.** These units are designed to provide continuous fresh air into the house while exhausting a similar amount of stale air. The fresh air supply is brought in and mixed with recirculated air picked up by the mixing box indoor return air inlet which could be located at ceiling level above the wood pellet stove. Six inch or smaller round ducts then deliver the warmed, fresh air throughout the house. The supply outlets should be located high on the walls, close to the ceiling.

The mixing box unit can be hung from the ceiling, near an outside wall, in the main living space of the house, for easy ductwork connections and access for cleaning of the air filter. The supply and exhaust ducts from outside the house to the mixing box should have insulation complete with sealed vapour barrier, plus dampers so that the quantity of ventilation air can be set. The ventilation capacity can be determined by following the National Building Code of Canada 1995 (in this case, about 35 L/s or 70 cfm). Exposed ducts that deliver the air throughout the house can be installed at ceiling level and can be painted to make them more attractive. Interior doors to rooms where supply air grilles are located should be undercut so that the space under the door equals the free area of the supply air grille. In that way, stale air can find its way back to the wood pellet stove and the mixing box return air inlet above it.

Note: this is offered for comparison only. It is not an energy efficient ventilation solution. (See higher cost #2.)

7. **Install blocks of two inch extruded polystyrene around the perimeter of the floor framing, between the floor joists.** Seal around all four edges of each block with solvent-free silicone sealant. Cover with gypsum board (with a front and back glass mat) or with cement board. Do not cover with regular gypsum board with a paper face and back.

8. **Monitor the condition of the crawl space.** With sealed poly on the floor and walls and better drainage, natural air movement to the main living area through any existing holes should keep the crawl space dry. Only if necessary, install a foundation exhaust fan to slightly depressurize the crawl space.

9. **Re-attach the loose siding on the west end.** Install the missing fascia. These items will help the building to shed water more effectively.

10. **Install eavestroughs and downspout extensions to direct water away from the foundation.**

11. **Airseal the main living area.** Air leaks were discovered around the back door, at electrical receptacles, light switches, light fixtures, plumbing vents and through the hall closet ceiling where the poly was missing. New sections of poly, gaskets, caulking and weatherstripping can be used to tighten up these penetrations. Do not seal the numerous plumbing and electrical penetrations through to the crawl space, since the crawl space must be considered as part of the conditioned space of the house.

12. **Purchase and regularly use a portable HEPA vacuum cleaner.**

13. **Re-install the water heater on a pre-cast concrete slab.** Remove the wooden base for the water heater. Install a level, evenly supported pre-cast concrete patio slab on top of the poly moisture barrier. Replace the top and bottom wiring covers.

Higher Cost Recommendations

1. **Damp-proof and backfill the foundation.** Caulk all joints in the plywood sheathing. Install 6 mil polyethylene sheeting or equivalent coating (or both) from about 75 mm (3 in) above the finished grade level to the bottom of the footing. Seal the top edge of the poly to the plywood wall all along its length. Protect the top edge of the poly with a 300 mm (12 inch) wide, 13 mm (1/2 in) thick, treated plywood cover strip. This cover strip could extend to the bottom of the siding and be protected from rain penetration by a metal flashing extending up under the siding. Protect the below grade corners with vertical plywood cover strips.

   As suggested in medium cost recommendation # 3, since there is no drainage layer under the foundation, install a perimeter drain tile beside the footing, complete with at least 150 mm (6 in) of crushed stone and a filter cloth. Provide a discharge line that runs out of the north hillside below the level of the footing.

   This is also an ideal opportunity to install at least a 600 mm (2 feet) wide horizontal strip of 63 mm (2 ½ in) Type 2 expanded polystyrene insulation over the footing, with a slight slope away from the building. In this climate, a 1.2 m (4 feet) wide insulation skirt would be preferred.

Bring in enough free-draining material for backfill. Cover the insulated footings, at least. Do not backfill higher than 200 mm (8 inches) below the level of the siding, making adjustment for any vent hoods. Ensure that the finished grade slopes away from the building on all sides.

2. **Install a fully ducted heat recovery ventilation (HRV) system.** There isn't an ideal location for an HRV. The back entry or laundry area could be used. The unit and ducts (which should terminate near the ceiling in each room) would be exposed in the living space. Installing the HRV in the crawl space is a possibility but it would involve greater expense in the installation of the high wall duct terminations and would pose problems for regular maintenance. In any case, a small HRV would provide an ideal ventilation system, as long as it was installed and maintained according to the manufacturer's instructions. The installation should include an electric duct heater of at least 1 kilowatt capacity, to ensure that the supply air is close to room temperature even during the coldest periods of the winter.

3. **Remove all of the drywall in the crawl space.** Replace it with a 5/8" gypsum board with inorganic glass mats embedded front and back (such as Dens-Glass Gold Fireguard from Georgia Pacific Ltd.) or a light, fibre-reinforced cement board (Durock made by Canadian Gypsum Company is one example), detailed according to manufacturer and building code specifications to create the required fire separation. The footing under the party wall will always be damp and will allow moisture to wick up into the wood framing. Drywall, with its paper face and back, is an ideal breeding ground for mold species that release spores that may be poisonous to humans. Drywall should not be used in this crawl space.

Energy Efficiency Recommendations

Table 3.1: House 2 Potential Energy Efficiency Upgrades			
Options	**Particulars**	**Estimated annual energy cost**	**Savings from current house**
This house	Airchange rate 2.80 ac/h @ 50 Pa; building envelope as is; no continuous mechanical ventilation; average annual natural and mechanical airchange rate = .116 airchanges per hour, pellet stove heating	$1,978	
This house vented	This house + 30 cfm continuous non-heat recovery ventilation = total airchange rate of .412 (similar to upgrade 11)	$2,078	Plus $100
Code house	This house if built to MNECCH prescriptive insulation values, 30 cfm continuous heat recovery ventilation, electric heat (or pellet stove heating)	$1,797 or $1,671	$181 or $307
Upgrade 1	Remove wet crawl space wall insulation; re-install dry R20 glass fibre batts with sealed poly a/v barrier.	$1,967	$11
Upgrade 2	Re-insulate as in option 1 plus airseal house to 2.0 ac/h @50 Pa	$1,964	$14
Upgrade 3	Re-insulate as in option 1 plus install R10 main floor header perimeter insulation	$1,963	$15
Upgrade 4	Re-insulate as in option 1; airseal to 2.0 ac/h as in option 2; install R10 header insulation as in option 3	$1,963	$15
Upgrade 5	Re-insulate as in option 1; install 2 foot wide R10 insulation skirt over outside of footing	$1,926	$52
Upgrade 6	Combine all above upgrades	$1,917	$61
Upgrade 7	Re-insulate as in option 1; 30 cfm continuous mechanical ventilation with heat recovery ventilator	$2,025	+$47
Upgrade 8	Re-insulate as in option 1; install footing insulation skirt as in option 5; 30 cfm continuous heat recovery ventilation	$1,968	$10
Upgrade 9	All building envelope upgrades above; 30 cfm continuous heat recovery ventilation	$1,964	$14
Upgrade 10	All building envelope upgrades above; 30 cfm continuous non-heat recovery ventilation	$2,020	+$42
Upgrade 11	All building envelope upgrades above; R10 crawl space floor insulation; R60 ceiling insulation; 30 cfm continuous heat recovery ventilation; total annual average airchange rate .421 airchanges per hour	$1,735	$243 ($343 less than this house vented)

Table 3.2: House 2 Estimated Upgrade Costs and Payback			
Upgrade Options	**Including (referred to IAQ rec. #s)**	**Estimated cost**	**Payback**
Renovating to code	Full crawl space floor insulation (R9), insulating sheathing and new siding (total R27), R 60 ceiling insulation, heat recovery ventilation	R10 crawl space floor $884 Patio slab insulation cover $1420 Wall sheathing & re-siding $4,500 Ceiling insulation $500 Heat recovery ventilation $1,800 Insulating & airsealing below $995 Total $10,099	$10,099 / $307 = 32.9 years
1. Repair crawl space wall insulation	M4 Re-insulate and airseal crawl space walls	3 extra bundles (49ft2) R20 $63 Poly already laying on floor Sheathing tape 1 roll $18 Caulking $30 Wood clamping strips from scrap Labour 8 hours @ $20 $160 Total $271	$271 / $11 = 24.6 years (a durability issue)
2. Option 1 plus airsealing to 2.0 ac/h @ 50 Pa	M3 sealed air moisture barrier on crawl space floor	1000 ft2 6mil poly $56 Sheathing tape $18 Caulking $30 Labour 4 hours @ $20 $80 Total crawl space floor costs $184	($285+271) / $14 = 39.7 years
	M9 airsealing of closet ceiling, back door, various penetrations	Closet ceiling poly and tape $5 Weatherstrip for back door $16 Miscellaneous small areas $20 Labour 3 hours @ $20 $60 Total M9 airsealing costs $101	
		Total airsealing costs M3 + M9 $285	
3. Option 1 plus R10 floor header insulation	M5 2" extruded polystyrene at floor perimeter between joists	5 2x8 sheets 2" xtps + cover $120 Caulking $30 Labour 4 hours @ $20 $80 Total $230	($230+271) / $15 = 33.4 years
4. Options 1, 2 and 3	M4, M3, M9, M5	Crawl space walls $271 Crawl space floor $184 Other airsealing $101 Header insulation $230 Total cost $786	$786 / $15 = 52.4 years
5. Option 1 plus footing insulation skirt	M4 plus H1 2' R10 EPS 2 polystyrene footing skirt (needed drainage & backfill not included)	Crawl space walls $271 12 2x8 sheets 2 ½" EPS 2 $149 Labour 3 hours $60 Total $480	$480 / $52 = 9.2 years
6. All above options combined	M4, M3, M9, M5, H1	Crawl space walls $271 Crawl space floor $184 Other airsealing $101 Header insulation $230 Footing skirt $209 Total $995	$995 / $61 = 16.3 year payback
7. Option 1	M4 plus H2 30 cfm	Crawl space walls $271	Plus $47 no

plus HRV	continuous heat recovery ventilation	Installed, fully ducted HRV $1,800 Total $2,071	payback
8. Option 5 plus HRV	M4, H1, H2	Crawl space walls $271 Footing skirt $209 HRV $1,800 Total $2,280	$2280 / $10 = 228 year payback
9. Option 6 plus HRV	M4, M3, M9, M5, H1, H2	Building envelope improvements $995 HRV $1,800 Total $2,795	$2795 / $14 = 199.6 year payback (24.5 year payback from this house vented)
10. Option 9 non heat recovery ventilation		Above total $2,795 Less ventilation cost difference $600 Total $2,195	Plus $42 no payback
11. Option 11		Building envelope improvements $995 HRV $1,800 Upgrade ceiling to R60 $500 R10 crawl space floor & cover $2,304 Total $5,599	$5,599 / $243 = 23 years (16.3 years from this house vented)

Energy Efficiency Recommendations Commentary

If this house had been built to MNECCH 1997 standards it would have lower operating costs and a payback period within the life expectancy of the house. Now, to make all of those energy efficiency changes along with the other changes listed in the summary plan below would require significant capital costs and a long payback period.

Water is wicking up through the footing and pwf framing as well as evaporating from the crawl space floor. This water migrates to the cold side of the insulation resulting in frost and condensation on the inside face of the pwf plywood sheathing. The effectiveness of the R20 glass fibre batt insulation has been reduced by 10% to account for this frost[11]. Re-insulating and installing a sealed air/vapour barrier on the crawl space walls is a logical place to start. However, it is a durability issue and has little effect on energy efficiency.

Heat is required for evaporation and released during condensation. The heat for evaporation must be produced by the home heating system. Some of it must be lost to the outside in this situation, where the condensation takes place on the cold side of the insulation. It is beyond the scope of this project to determine the annual energy consumption for this process.

The house is already reasonably tight. Making it tighter will not save much energy. Reducing the airchange rate from 2.8 to 2.0 airchanges per hour at a 50 Pa pressure difference would only save about $4.11 worth of energy per year (plus $10.51 realized by improving the crawl space walls). Airsealing the large ceiling hole in the hall closet and installing a sealed crawl space floor moisture barrier are still recommended for indoor air quality and durability reasons.

Options 3 to 6 above will improve building durability by providing less cold surfaces available for condensation but, due to the long payback periods, they cannot be justified as energy efficiency improvements.

This house has a poor supply of fresh air and circulation of air within the space. The wood pellet stove does provide a reasonably continuous 45 cfm exhaust during the heating season but it does not circulate air to the bedrooms and bathroom. A properly installed HRV will provide much better indoor air quality and building durability.

Building envelope improvements as suggested in option 11 will take a long time to provide sufficient energy savings to offset the operating cost of the HRV. Nevertheless, without ventilation and air circulation, this building will not last. With them, the capital cost payback is within the expected lifespan of the building.

This house should be finished and provided with continuous heat recovery ventilation. This building is only a year old. It was not designed to current standards. It isn't finished. It seems well worthwhile to finish it according to the following plan, thereby creating more favourable conditions for occupant health and comfort along with building longevity.

Table 3.3 House 2 Renovation Plan for Indoor Air Quality, Durability and Energy Efficiency Note: Costs for measures that must include both duplex units will double.	
No cost / lower cost recommendations	**Cost**
1. Install a carbon monoxide detector in the main living area.	$75
2. Discourage smoking in the house.	$0
3. Continue to clean up small areas of mold.	$0
4. Fix the leak in the plumbing drain in the crawl space (glue the joint).	$30
5. Replace the flexible, plastic exhaust duct in the attic.	$100
6. Vent the dryer outside through rigid, aluminium duct.	$80
7. Clean the debris out of the crawl space.	$0
8. Inventory the cleaning chemicals in the house and discard those that are not necessary.	$0
9. Keep kitchen garbage in a smaller, covered container that is emptied daily.	$10
10. Install a plastic dam at the head of the bath-tub.	$10
11. Undercut all interior doors (or leave them open as much as possible).	$40
12. Minimize the plants in the house.	$0
Total	**$345**
Medium cost recommendations	
1. Relocate the pellet stove sidewall vent not less than 4 feet horizontally from the window.	$200+
2. Install a sealed moisture barrier over the crawl space dirt floor.	$184
3. Remove and replace any wet glass fibre insulation from the crawl space walls. Install a sealed air/vapour barrier.	$271
4. Insulate and airseal the perimeter of the main floor framing.	$230
5. Re-attach loose siding. Install the missing fascia.	$100
6. Install eavestroughs, downspouts and extensions.	$320
7. Airseal the main living area.	$101
8. Re-install the water heater on a solid base.	$80
Total	**$1,486**
Higher cost recommendations	
1. Damp-proof the portion of the foundation that will be below finished grade.	$360
2. Install foundation perimeter drainage.	$300
3. Install R10 footing insulation 2' wide.	$209
4. Install R10 crawl space floor insulation and patio slab cover.	$2,304
5. Upgrade ceiling insulation to R60.	$500
6. Backfill the foundation and slope the finished grade away from the house.	$600
7. Install a fully ducted heat recovery ventilator.	$1,800
8. Replace the crawl space drywall with gypsum or cement board (detailed as required).	$600
Total	**$6,673**
Total indoor air quality, durability and energy efficiency recommendation costs	**$8,504**

Conclusions

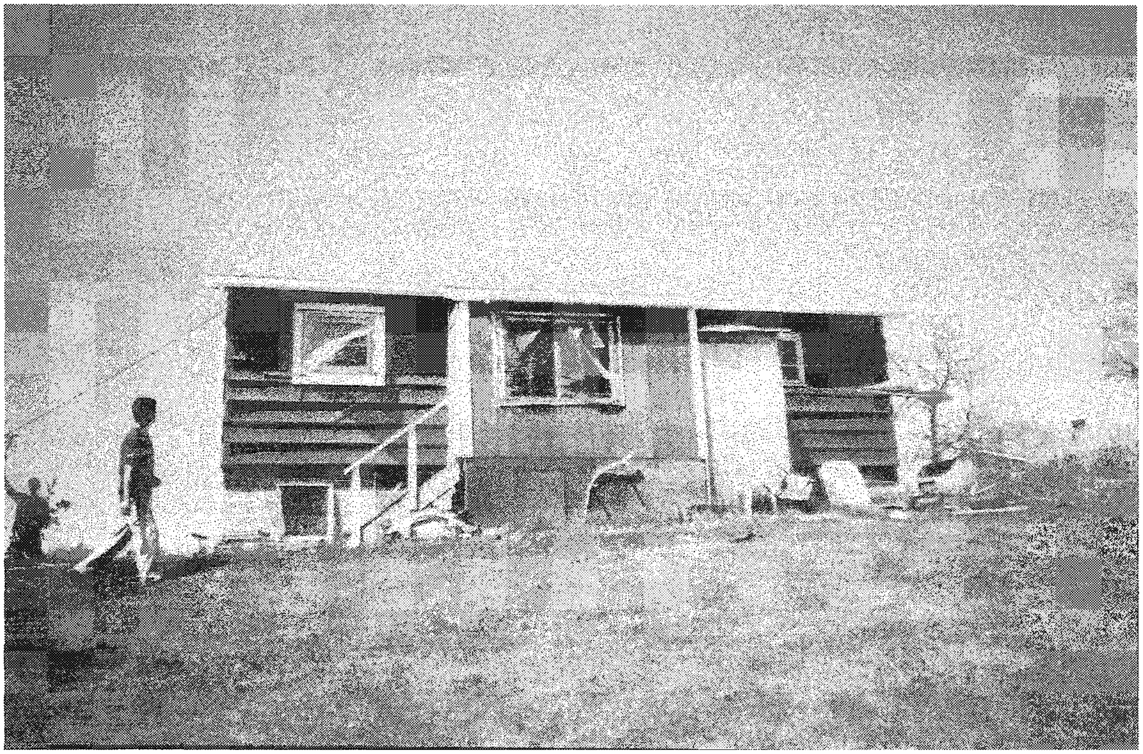
The anticipated annual energy savings from current house = $243

The renovations capital cost payback period = $8,504 / $243 = 35 years

Energy savings can only be expected to offset, not completely recover, capital costs. The energy efficiency of the current house is due to good airtightness, reasonable insulation values and no continuous mechanical ventilation (an unfair comparison; at similar total airchange rates the payback period would be 24.8 years). Without drainage, a crawl space moisture barrier, air circulation and continuous ventilation this house will deteriorate quickly. The investment into its recent construction will be lost.

Chapter 4: House Investigation Number Three

Figure 6: House 3, southeast side



The Occupant's Perspective

The band owns this house, which was built about 1970. The five present occupants (a man, woman, two teens and a four year old boy) have lived here since 1987. They notice a musty odour when they enter the home. Odours linger in the bathroom. They would like to have new siding, new ceiling finish, a bathroom renovation, insulation of the crawl space and a new bedroom addition to the house.

The bedroom windows are cold. The air is dry in winter and a room humidifier is used occasionally. Water comes in the kitchen ceiling during a heavy rain. Items stored in the crawl space become damp. The water supply line in the crawl space freezes at times.

Windows are opened in summer for ventilation. The bathroom exhaust fan is used regularly. Everyone removes shoes when entering the home.

There are problems with ants, spiders and mice. Over-the-counter pest control products are used for the ants and spiders when necessary in summer.

Several occupants smoke in the house.

The four-year old boy has been diagnosed with asthma. He is home all day. He coughs and has wheezy breathing when exposed to the musty smell.

Site Observations May 16, 2000

Weather
Clear, sunny, calm, 22C, RH 60%
Dry ground conditions

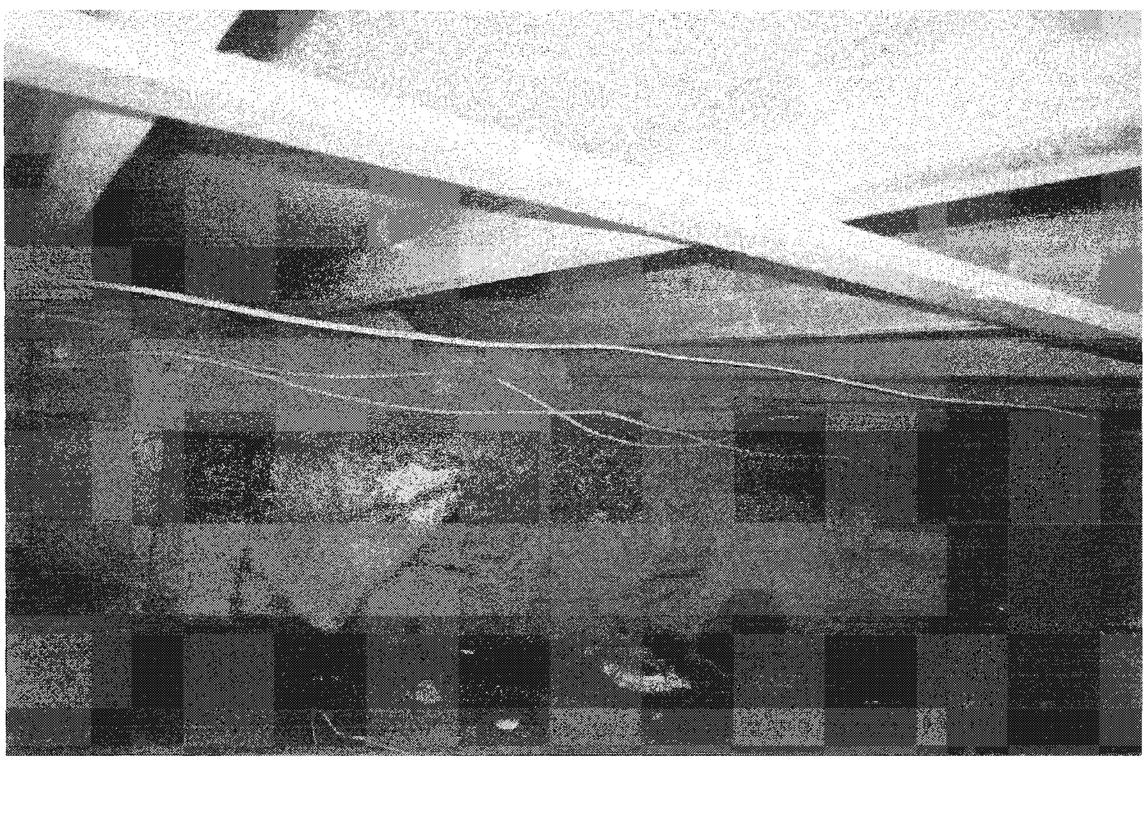
Limitations to the investigation
One half of the crawl space is inaccessible

Exterior
Detached house on small hill above lake
Steep slope to lake
Ground slopes away on three sides, rock slope toward house on northeast side
Miscellaneous materials piled against house on northeast side
Good sun exposure and airflow
Concrete block crawl space foundation
Wood frame construction, hardboard siding over ½" asphalt impregnated fibreboard
Siding warped, buckled, corners and joint connectors missing
Old, weathered, single and double glazed wood slider windows, some exterior storms, some temporary poly storms, some screens, no flashing just caulking
Steel polyurethane core or wood doors
Wood soffits with spot vents
Metal and wood fascia
Some vinyl eavestroughs, downspouts not connected
Asphalt shingles, chimney flashing loose
Damaged gable vents

Attic
Trusses @ 24" on centre
R12 plus R12 glass fibre batts
Unsealed poly air/vapour barrier

Foundation
T 16C, RH 60%
Access hatch from main floor
Uninsulated dirt floor, damp at galvanized water pipe section below hatch
Electric heater laying on ground, disconnected
No crawl space ventilation
Concrete block walls, deteriorated at bottom course southwest side, freeze-thaw
Three inches of expanded polystyrene on inside of block walls
Crawl space ceiling not airtight but insulated with R12 glass fibre batts held up with ¼" hardboard
Rim joist insulated with R12 glass fibre batts, no air/vapour barrier
Some storage on dirt floor
Only the northwest side of the crawl space is accessible – glass fibre batts at the main floor beam split the crawl space in half – other side looks similar but difficult to see

Figure 7: House 3 crawl space



Mechanical systems
Main floor centrally located Envirofire EF II induced draft, vertically vented, wood pellet stove
Electric water heater, 40 gallons, located in hall outside bathroom
No laundry equipment

Main level building envelope
Main walls ¼" wood panelling, 2x4 @ 16" o/c, R12 glass fibre batt insulation assumed, fibreboard sheathing, hardboard siding
Airchange rate at 50 Pascal pressure difference = 7.87 airchanges per hour

Kitchen
T 22C, RH 68%
Vinyl sheet flooring, fair condition
Wood panel walls, fair condition
Ceiling tile removed, strapping and poly remain
Window- water stains, air leakage
No direct heating or ventilation
Typical cleaning chemicals
Large open indoor garbage storage

Bathroom
T 22C, RH 68%
Vinyl sheet flooring, fair condition
Wood panel walls, fair condition
Barker board around tub
Ceiling tiles, fair condition
Single glazed wood slider window, waterstains
Barker board on wall beside head of tub deteriorated from water
Condensation and mold on bottom of unlined toilet tank
Exhaust fan vented outside
No direct heating noted

All bedrooms
Vinyl sheet flooring, fair condition
Wood panel walls, fair condition
Ceiling tile, fair condition
Windows, water stains, condensation, poor condition
No direct heating or ventilation
Cluttered

Living room
Vinyl sheet flooring, fair condition, area rug
Wood panel walls, fair condition
Ceiling tile removed, strapping and poly ceiling
Central pellet stove
Two ceiling circulating fans
Windows weathered, water stains, poor condition

Indoor Air Quality Recommendations

These recommendations are divided into measures that can be done easily at no or low cost, measures that are of medium cost and finally some measures that are of higher cost. In each category, the recommendations are listed in approximate order of their indoor air quality significance. Some recommendations that serve similar purposes may be found in two or three categories. They are offered as options.

Lower Cost Recommendations

1. **Install a carbon monoxide detector in the main living area.**

2. **Discourage smoking in the house.** Smoking by anyone, in any room, will result in second-hand smoke dispersing throughout the house, affecting all occupants. The effects of environmental tobacco smoke are well documented.

3. **Clean up small areas of mold.** There is a small amount of mold on the underside of the toilet and on the wall behind the toilet. For any small mold cleanup, wear rubber gloves, glasses or safety goggles, a dust mask and a shirt with long sleeves. Throw out wet and badly damaged or musty smelling materials. For washable surfaces, scrub with a detergent solution; then sponge with a clean wet rag and dry thoroughly. Find the source of the water and eliminate it. Otherwise the mold will return. In this case the mold appears to be due to condensation on the toilet tank and to water leaking over the edge of the tub. Look for small areas of mold or moldy articles throughout the house.

4. **Investigate and repair the source of the kitchen ceiling water leak.** The home occupant has reported a leak after heavy rains. There is no obvious roof leak directly above the kitchen, although the loose chimney flashing should be repaired. The plumbing vent stack penetration is another potential leak area. Investigate further and repair the leak.

5. **Install a plastic dam at the head of the tub.** These small self-adhesive plastic dams can be fastened to the rim of tub and help (slightly) to reduce leaks over the edge of the tub during showers.

6. **Set spring-loaded mousetraps in the house continuously.** Use gloves when handling dead mice. Put dead mice in plastic bags and dispose of them promptly. Use steel wool or cement to seal, screen, or cover all openings into the home that are larger than .5 cm (1/4 inch). Keep food and water covered and stored in rodent-proof metal or thick plastic containers with tight fitting lids. Wash dishes and cooking utensils immediately after use. Remove all spilled food promptly. Outside, reduce rodent shelter and food sources near the house by hauling away trash or anything that may serve as a rodent nesting site. Cut grass and brush near the house.

7. **Keep kitchen garbage in a smaller, covered, container that is emptied daily.** Protected outside garbage storage is essential.

8. **Caulk around all windows and doors.** The windows and doors do not have effective flashing or caulking. Caulking will help to minimize water leaks.

9. **Check the water supply line valve in the crawl space for leaks.** Repair if necessary. There is a wet patch on the crawl space floor at the water supply valve. It is not clear whether this is due to a leak or to condensation on the galvanized section of pipe.

10. **Restrict the access of the dogs throughout the house.** Dogs and cats are a source of dust, hair and allergens that can affect the indoor air quality.

11. **Re-connect the eavestrough downspouts.** Ensure that the eavestroughs are clear and that joints are sealed. Add downspout extensions to deposit water further from the building.

12. **Use the bathroom fan frequently.** There is a high level of humidity in the house. Using the bathroom fan frequently will help to reduce humidity and prevent condensation and mold growth.

13. **Clean the debris out of the crawl space.** Cardboard boxes and other items provide food for molds and obstruct air circulation. This crawl space should not be used for storage.

14. **Re-attach and re-connect (or replace) the crawl space electric heater.** The heater is lying on the dirt floor and is not wired. A warmer crawl space would be less likely to have mold growth. In addition, the water supply line would be better protected from freezing.

15. **Inventory the cleaning chemicals in the house and discard those that are not necessary.** Minimize the use of air fresheners and cleaning chemicals. Unscented dish detergent, baking soda and water, or vinegar and water are some of the alternative cleaners that can be used to reduce the chemicals in the house.

16. **Move any materials piled against the outside of the house.** Particularly on the northeast side, materials piled against the house may prevent the best possible air circulation and drying of the house.

Medium Cost Recommendations

1. **Replace the deteriorated barker board finish behind the toilet.** The barker board and baseboard have suffered water damage and mold. To minimize the spread of any mold spores, place discarded materials into doubled garbage bags when carrying them out of the house. Follow the precautions listed in lower cost recommendation #3.

2. **Install a sealed moisture barrier over the crawl space dirt floor and walls.** Lay sheets of 6mil or preferably thicker polyethylene, tough enough to resist tears, over the whole floor. Overlap and seal joints with caulking or sheathing tape. Seal the main sheets of poly to the edges of the post footings. At the edges of the floor, ensure that the poly extends up to the top of the foundation walls. Seal it to the top of the expanded polystyrene just below the floor joists. A sealed floor and wall air and moisture barrier is an important step in reducing moisture in the crawl space as well as in the rest of the house. Installing this poly is a difficult task due to the lack of headroom and working space available.

3. **Re-grade the northeast side.** If possible, with the rock so close to the surface, re-grade the northeast side to direct water away from the building. As well, it may be possible to install a drainage tile, filter fabric and crushed stone along the side of the footing on the northeast side. The tile could drain out the side of the hill on the northwest and southwest sides of the house.

4. **Re-attach the siding.** There are numerous corners and joint connectors missing. Some siding is poorly attached. The siding will help to prevent the building from rain and snow penetration if it is re-attached and the missing connectors are replaced.

5. **Airseal the main living area.** Air leaks were discovered around the doors, windows, electrical receptacles, light switches, behind the baseboard along the bottom edge of the exterior walls, around plumbing vents and through joints in the living room and kitchen ceiling poly. Gaskets, caulking and weatherstripping can be used to tighten up these penetrations. As well, there were numerous plumbing and electrical penetrations through to the crawl space, so the crawl space must be considered as part of the conditioned space of the house.

6. **Install storm windows over all single glazed windows.** Storm windows will reduce air leakage and provide warmer inside glass surface temperatures, thereby reducing the potential for condensation and mold growth (see higher cost #1).

7. **Install a small foundation exhaust fan.** Wire the fan to operate continuously to provide a very small amount of exhaust sufficient to keep the air pressure in the crawl space slightly lower than the air pressure in the main living space or outside.

8. **Replace the gable vents.** The aluminium gable vents are in poor condition and may allow rain, snow, insects or birds into the attic.

Higher Cost Recommendations

1. **Install new windows and doors.** Some of the windows are single glazed with either glass or plastic storm windows. The southeast door is wood. These windows and that door should be replaced. New windows should be at least double glazed with one Low E coating and argon fill. The wood door should be replaced with a steel clad, polyurethane core door. Any other windows in poor condition should also be considered for replacement. Window installation should include effective flashing and caulking.

2. **Install an air exchanger ventilation air mixing box or, for greater energy efficiency, a heat recovery ventilation system, as described for houses 1 and 2.**

3. **Install new siding, soffits and fascia.** A new exterior would help to protect the building from the elements. Any new siding should be installed following the rain-screen principle.

Any major renovations of this house should also address the deteriorated section of the concrete block foundation on the southwest side. As well, this is a very shallow foundation with the footings on the southwest side exposed above grade. This foundation would be better protected with an insulation skirt around the perimeter, dampproofing, perimeter drainage and backfill at least covering the insulation skirt.

Energy Efficiency Recommendations

Table 4.1: House 3 Potential Energy Efficiency Upgrades

Options	Particulars	Estimated annual energy cost	Savings from current house
This house	Airchange rate 7.87 ac/h @ 50 Pa; building envelope as is; no continuous mechanical ventilation; annual average natural + mechanical airchange rate = .393 airchanges per hour (very close to upgrade 7)	$2,259	
Upgrade 1	Airsealing to 3.57 ac/h @ 50 Pa (present day levels)	$2,114	$145
Upgrade 2	Add storm windows to single glazed units (upgrading all windows to double glazed)	$2,220	$39
Upgrade 3	Both airsealing and storm windows as above	$2,079	$180
Upgrade 4	Airsealing and storm windows as above; plus 2' wide R10 insulation skirt over footing	$2,037	$222
Upgrade 5	Airsealing; storm or double glazed windows; R10 footing insulation skirt; R7 insulating sheathing; strapping; siding	$1,962	$297
Upgrade 6	Airsealing; storm or double glazed windows; R10 footing insulation skirt; 30 cfm continuous non-heat recovery ventilation	$2,168	$91
Upgrade 7	Airsealing; storm or double glazed windows; R10 footing insulation skirt; 30 cfm continuous heat recovery ventilation; average annual mechanical and natural airchange rate .407 airchanges per hour.	$2,106	$153

Table 4.2: House 3 Estimated Upgrade Costs and Energy Savings Payback			
Upgrade	**Including (referred to IAQ rec. #s)**	**Estimated cost**	**Payback**
1. Airsealing	L8 Caulk around windows and doors M2 Crawl space poly air/vapour/moisture barrier M6 Airsealing	Crawl space poly 1500 ft2 6mil poly $84 2 rolls sheathing tape $36 Door weatherstrip, caulking, foam, gaskets$200 Labour 32 hours @$20 $640 Total $960	$960 / $145 = 6.6 years
2. Storm windows	M7	4 aluminium storm windows 3 @ $90 $270 1 @ $110 $110 Labour 2 hours @ $20 $40 Total $420	$420 / $39 = 10.8 years
3. Airsealing and storm windows	L8, M2, M6, M7	Airsealing $960 Storm windows $420 Total $1380	$1380 / $180 = 7.7 years
4. 3 + footing insulation	L8, M2, M6, M7	Airsealing $960 Storm windows $420 15 sheets 2 ½" EPS 2 $186 1 truckload dirt/sand cover $60 Insulation and covering labour 16 hours $320 Total $1946	$1946 / $222 = 8.8 year payback
5. 4 + insulation and siding	L8, M2, M6, M7, H3	Above items $1946 32 sheets 1 ½" EPS ($12) $384 Soffits and fascia (installed) @ $8/lin.ft. $896 Wood fibreboard siding (installed) @ $4.50/sq.ft. $4536 Total $7762	$7762 / $297 = 26.1 year payback
6. 4 + ventilation	L8, M2, M6, M7, H2	Option 4 $1946 30 cfm continuous non-heat recovery ventilation (installed) $1200 Total $3146	$3146 / $91 = 34.6 years
7. 4 + heat recovery ventilation	As above except with HRV	Option 4 $1946 HRV installed $1800 Total $3746	$3746 / $153 = 24.5 years

Energy Efficiency Recommendations Commentary

This house is 30 years old. With a multitude of small problems, its monetary value is low. However, its value to the community must be considered from the perspective that it does provide shelter for 5 people. The current occupants have tried their best to keep the house warmer by insulating and installing temporary storm windows.

Few of the above energy efficiency options seem worthwhile, given the monetary value of the house. Some airsealing and temporary plastic storm windows seem to be the most cost effective options.

Upgrading the mechanical ventilation does not seem worthwhile. Continued use of the bathroom exhaust fan along with building air leakage (even after some airsealing) may be the most cost-effective way of providing some ventilation. Air circulation can be provided by use of the circulating fans and leaving room doors open.

Spend a little on maintenance, not a lot on renovations. Rather than spending a lot of money on this house, it would seem most prudent to spend a little on maintenance options (such as re-attaching the existing siding). The occupants and the community might be better served by a budget including replacement of this house as soon as possible.

Table 4.3: House 3 Renovation Plan for Indoor Air Quality, Durability and Energy Efficiency

No cost / lower cost recommendations	**Cost**
1. Install a carbon monoxide detector in the main living area.	$75
2. Discourage smoking in the house.	$0
3. Clean up small areas of mold.	$0
4. Install a plastic dam at the head of the bathtub.	$10
5. Investigate and repair the source of the kitchen ceiling water leak.	$80
6. Set mouse traps continuously.	$0
7. Keep kitchen garbage in a smaller, covered container.	$10
8. Check the water supply line valve in the crawl space for leaks.	$50
9. Restrict the access of the dogs throughout the house.	$0
10. Re-connect the eaves-trough downspouts.	$60
11. Use the bathroom fan and ceiling re-circulating fan frequently.	$0
12. Clean the debris out of the crawl space.	$0
13. Re-connect the crawl space electric heater.	$60
14. Inventory chemicals in the house and discard those that are not necessary.	$0
15. Move the materials piled against the house.	$0
Total	**$345**
Medium cost recommendations	
1. Replace the barker board finish behind the toilet.	$200
2. Install a moisture barrier over the crawl space dirt floor.	$280
3. Caulk around windows and doors; install plastic storm windows annually.	$200
4. Manually re-grade the northeast side.	$80
5. Re-attach the siding.	$200
6. Straighten and screen the gable vents.	$40
Total	**$1,000**
No higher cost recommendations	**$0**
Total indoor air quality, durability and energy efficiency recommendation costs	**$1,345**
Anticipated annual energy savings from current house are very minor. The proposed renovations will temporarily repair some problems until the house can be replaced.	

Chapter 5: House Investigation Number 4

Figure 8: House 4, northeast side

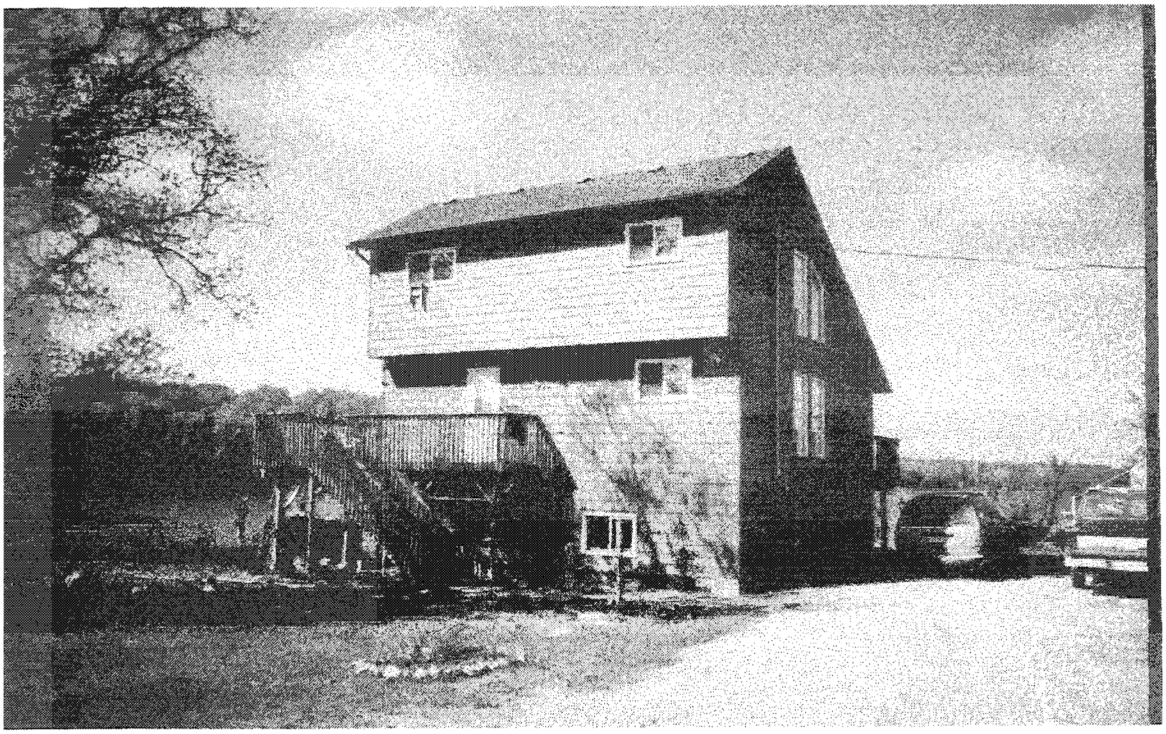
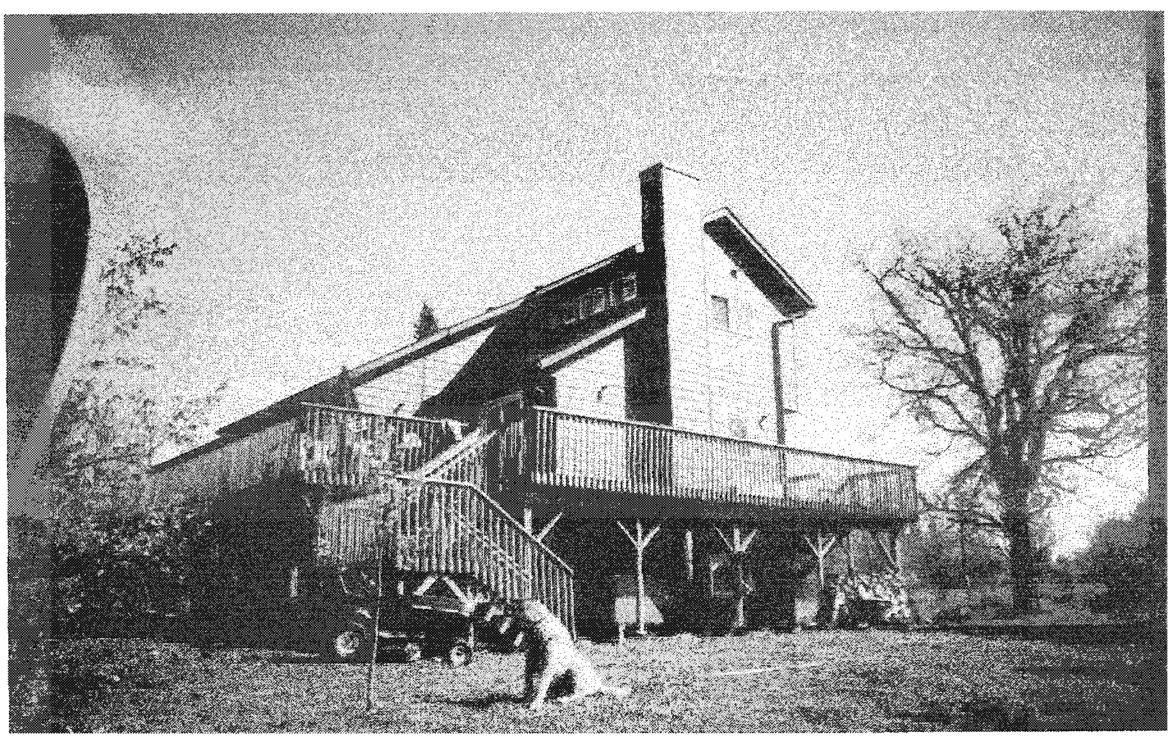


Figure 9: House 4, southeast side



The Occupant's Perspective

The band owns this house. The house was built from 1993 to 1994 and first occupied in August of 1995 by the five present occupants: a man, a woman and three children. The occupants agreed to an investigation to provide a house with a full basement for the project. No one in the family is experiencing any health problems that may be affected by the quality of the air in the home.

From 1995 to 1998, the occupants finished the basement. There have never been any floods. The only plumbing leak was very minor.

The air in the house is dry in winter. A furnace-mounted humidifier is used. Water rarely condenses on windowpanes. The three bathroom exhaust fans are used regularly. The kitchen range hood was rarely used and has been taken out. The fresh air supply to the return air plenum causes freezing problems for the hot water coils so it has been almost totally blocked.

Drycleaning is rare. Everyone removes their shoes when they enter the home. A central vacuum is used twice a week. No pest control products are used inside the home or outside on the lawn.

Both occupants quit smoking in March and conducted a thorough spring-cleaning to rid the house of smoke odours. A dog is kept outside and a cat is kept inside.

Site Observations May 17, 2000

Weather

Clear, sunny, calm, 14C, RH 50%
Dry ground conditions

Limitations to the investigation

None

Exterior

Detached house on open, well drained site overlooking the lake
Flat grade, light, rocky soil
Good sun exposure
PWF shallow, full height foundation with basement walkout at grade level
Asphalt impregnated fibreboard protective covering over poly foundation dampproofing, missing or deteriorated at northeast corner
Wood frame construction with hardboard siding
Triple glazed clear, air fill, metal edge spacer, wood frame windows
Three bathroom exhaust hoods
One kitchen range exhaust hood (blocked)
One central vacuum outside exhaust
One boiler combustion air supply
One fresh air supply (mostly blocked)
Vented metal soffits
Metal fascia – one piece missing on the southwest
Complete eavestroughs
Downspouts extend below grade
Medium and steep slope roofs, asphalt shingles, good condition
Roof spot vents
Exterior prefabricated metal chimney for wood stove – not used
Chimney cap removed – lying on deck

Attic

Accessible through ceiling hatch
Insulated with 12 inches plus of glass fibre batts in sloping ceiling
Insulated with 12 inches plus of blown cellulose above flat ceiling
Ventilated, good condition

Foundation

T 18C, RH 48%
Full, finished, shallow PWF foundation
Family room, bedroom, bathroom, mechanical room and entry
Bathroom and entry on raised, wood frame floor, bathroom vinyl flooring
Family room and bedroom carpeted on concrete floor
Mechanical room concrete floor
Basement walls 2 x 8 PWF at 16" on centre with glass fibre batt insulation
Exposed 2" extruded polystyrene used to insulate perimeter of main floor framing – not continuous, not sealed

Suspended ceiling and painted drywall walls in finished basement areas
Basement bedroom has slight mold on window

Mechanical systems
Located in basement mechanical room
Forced air heat distribution
Oil fired Kerr K-26 direct vent boiler uses air handler from original wood furnace
Oil storage outside
Clean 1" glass fibre filter
Furnace mounted humidifier - clean
Galvanized metal ducts
Domestic hot water – original electric tank wiring disconnected – tank used as storage tank for hot water from boiler
Outdoor air supply to return trunk of furnace partly blocked with cardboard and wood outside plus damper closed – un-insulated duct
Poor air seal around chimney vent through wall

Main levels building envelope
Main walls drywall, 2x6 framing @ 16" o/c, R20 glass fibre batts assumed
R40 ceilings
Airchange rate at 50 Pascal pressure difference = 2.55 airchanges per hour

Kitchen
T 19C, RH 47%
Vinyl sheet floor, good condition
Forced air supply
Painted drywall walls and ceiling, good condition
Plastic laminate countertop, mdf base
Mdf cabinets
No visible plumbing leaks, good venting and trap
Range hood disconnected
Refrigerator evaporation pan clean
Small indoor garbage storage emptied daily
Excellent housekeeping

Bathroom – main floor
T 20C, RH 48%
Vinyl sheet floor, good condition
Painted drywall walls and ceiling, good condition
No window
Toilet (lined) and sink
Formed vanity top, mdf cabinet
No visible plumbing leaks, good venting and trap
Forced air supply
Exhaust fan vented outside, controlled by switch, approximately 30 cfm flow
No scented products
Excellent housekeeping

Laundry room
Same finish as above
Dryer exhaust flex duct

Main floor bedroom
T 21C, RH 48%
Carpeted floor, good condition
Painted drywall walls and ceiling, good condition
Window good condition
Furniture good condition
Moderate storage in closets
Forced air heating supply
No mechanical ventilation
No plants
Excellent housekeeping

Living room
T 20C, RH 47%
Carpet, foam chip underlay, good condition
Painted drywall walls and ceiling, good condition
Windows good condition, some air leakage
Some candles
Forced air heating supply
No mechanical ventilation
No plants
Moderate amount of furniture and storage
Excellent housekeeping

Upstairs bedrooms
T 22C, RH 46%
Carpet, good condition
Painted drywall walls and ceiling, good condition
Windows good condition
Forced air heating supplies
No mechanical ventilation
Excellent housekeeping
Smoke detector 2nd floor hall

Upstairs bathroom

T 22C, RH 46%
Sheet vinyl floor, good condition
Painted drywall walls and ceiling, good condition
Exhaust fan about 15 cfm flow
Excellent housekeeping

Indoor Air Quality Recommendations

These recommendations are divided into measures that can be done easily at no or low cost, measures that are of medium cost and finally some measures that are of higher cost. In each category, the recommendations are listed in approximate order of their indoor air quality significance. Some recommendations that serve similar purposes may be found in two or three categories. They are offered as options.

Lower Cost Recommendations

1. **Clean up the slight mold along the bottom edge of the basement bedroom window.** For any small mold cleanup, wear rubber gloves, glasses or safety goggles, a dust mask and a shirt with long sleeves. For washable surfaces, such as this, scrub with a detergent solution; then sponge with a clean wet rag and dry thoroughly. Water condensing on the cold window surface is the likely cause of this mold. Leaving the window blinds open more often will allow better air circulation against the glass surface and will reduce condensation. Otherwise the mold will return.

2. **Restrict the access of the cat and dog throughout the house.** Pets are a source of hair, dander, dust and other allergens. Restricting their access to the whole house will simplify cleaning and reduce exposure to allergens.

3. **Minimize the use of candles.** Combustion from candles is very incomplete and releases a great deal of soot into the air. Minimize or eliminate the use of candles.

4. **Inventory the cleaning chemicals in the house and discard those that are not necessary.** There were very few chemicals in use in this house. However it is a good idea to periodically review and minimize the use of strong chemicals. Unscented dish detergent, baking soda and water, or vinegar and water are some of the alternative cleaners that can be used.

5. **Replace the dryer flex duct.** Replace as much of the plastic flex duct as possible with smooth-walled aluminum duct, complete with sealed joints, installed in the shortest, straightest route possible.

6. **Replace the glass fibre furnace filter.** Although the filter was relatively clean, this type of filter only captures large particles that might harm the furnace fan. This filter will do nothing to capture smaller particles that might be inhaled by house occupants. A better choice would be a 25mm electrostatically charged media filter (such as the "3M Filtrete"). Although more expensive, they provide good economy in relation to the amount of clean air delivered and will fit in the same slot as the glass fibre filter. Keep in mind, however, that no central furnace-mounted filtration will be able to keep up with the dust generated in the living space by human activities. First of all, there is no filtration unless the furnace fan is running. Secondly, particulate exposure is better controlled by actions such as removing shoes on entry, keeping major dust generators (like smoking and pets) out of the house, vacuuming with the central outside exhausting vacuum and reducing the entry of particle-laden outdoor air by improving house air tightness and installing an intake filter on any air supply.

7. **Replace the missing cover over the poly foundation dampproofing at the north corner.** The poly that protects the foundation from dampness is exposed at the north corner. To prevent it from deteriorating due to abrasion or sunlight,

cover it above grade with a small section of pwf plywood (see medium cost #4).

8. **Install metal fascia where it is missing on the southwest side.** To continue to protect the building envelope from water, replace the missing fascia.

9. **Replace the chimney cap.**

10. **Do not seal the range hood exhaust duct permanently.** Having the exhaust duct in the wall will allow the range hood to be re-installed in future if that proves to be necessary. An outside exhausting range hood is a good way to expel moisture and cooking odours at the source.

Medium Cost Recommendations

1. **Move the fresh air supply duct further along the return air trunk away from the return air plenum.** Restricting or eliminating the only source of fresh air is not a good solution to the problem of freezing the water coils in the plenum. Moving the fresh air entry into the return air system further from the plenum will allow better mixing of the cold air with the returning house air before it meets the water coils. This tempered air will be much less likely to cause freezing problems. As well, any fresh air supply duct should be insulated, complete with a sealed air/vapour barrier wrap, to prevent condensation on the cold duct. (See higher cost #1.)

2. **Airseal the main living area.** Air leaks were discovered around both of the patio doors, the slider part of some windows, electrical receptacles and light switches. Gaskets, caulking and weatherstripping can be used to tighten up these penetrations. There is a major air leak around the furnace vent to the chimney. A galvanized metal ring, cut in two halves, can be slipped around this vent. The wall poly can then be sealed to the ring. Better control over air leakage gives better control over indoor air quality.

3. **Insulate and airseal the perimeter of the floor framing.** Blocks of extruded polystyrene have been used to insulate the perimeter of the floor framing. However, some are missing and none have been sealed around all four edges to create a continuous air barrier. Complete the installation of insulating blocks. Note: according to NBCC 9.10.16.10, all of these blocks of extruded polystyrene must be protected from fire by an interior finish such as drywall. Pieces of drywall should be installed over each block and sealed along all four edges to the framing (and wall poly, where possible) and sub-floor above, in order to create a continuous air barrier.

4. **Install pwf plywood on the above grade portions of the foundation to replace the asphalt impregnated fibreboard used as a foundation dampproofing cover.** The fibreboard is showing signs of deterioration. It absorbs water and will not provide long-term protection for the foundation dampproofing. A strip of pwf plywood, with a top metal flashing slipped up under the siding, could be installed to cover the foundation above grade.

Higher Cost Recommendations

1. **Install a heat recovery ventilation (HRV) system.** This type of whole house ventilation system usually includes exhaust ducts from the kitchen and bathroom leading through the heat recovery ventilator and terminating on the outside of the house. An equal amount of fresh air is supplied through the HRV, where it recovers heat from the air being exhausted, and terminates in the return air duct of the furnace. Thus, there is a continuous exhaust of stale air and a continuous supply of an equal amount of fresh air that is then warmed further and distributed by the forced air heating system throughout the house.

In this house it would be very difficult to install exhaust ducts high in the wall of the bathrooms and kitchen. However, a simplified duct system could be installed. In such a system, the exhaust ducts remove a portion of the air from the return air trunk and exhaust it through the HRV. The supply ducts from the HRV deliver the same amount of fresh air to the return air system, closer to the furnace. The small amount of ductwork required would be in the basement.

To distribute the air, the furnace fan must also run continuously. This can be a heavy energy penalty without an energy efficient fan motor, so such a fan motor is also recommended.

The installer should be certified as a Heating, Refrigeration and Air Conditioning Institute (HRAI) Residential Mechanical Ventilation Installer. The installation must be designed for the size of the house and installed to conform to currently accepted industry standards.

The existing bathroom exhausts could still be used to supplement the whole house HRV system, as required.

2. **Replace the carpets with hard surface flooring.** Carpets are a source of chemical emissions, particularly when they are new. They provide a haven for dust mites and mold when they are old. These carpets are in very good condition and are very well kept. However, when they have reached the end of their useful lifespan, consideration should be given to replacing them with harder surface flooring such as pre-finished hardwood. Washable area rugs could be used for comfort.

This house is in very good condition and is immaculately maintained by the occupants, none of whom are experiencing health problems that might be attributable to poor indoor air quality. Although it lacks continuous mechanical ventilation, it probably already has air quality that is superior to many houses in Canada. All of the above recommendations should be considered from that perspective.

Energy Efficiency Recommendations

The existing building envelope insulation values and airtightness, space heating system, and domestic hot water heating system are all adequate. Improvements are not warranted.

Airsealing the main living area and insulating and airsealing the perimeter of the floor framing, as suggested in the IAQ recommendations, are actions designed to protect the integrity of the building envelope. They will enhance durability slightly but will make little difference in energy efficiency.

What this building lacks is a continuous supply of a modest amount of fresh air and continuous exhaust of a modest amount of stale air. This can be accomplished either with or without heat recovery. Either option will have attached capital and operating costs. Either option could be installed with a simplified duct system as described in higher cost #1.

Table 5.1: House 4 Potential Upgrades and Payback					
Options	**Particulars**	**Estimated annual energy costs**	**Operating cost difference**	**Capital cost difference**	**Payback**
Current house	As described; average annual natural + mechanical airchange rate .128 ac/h.	$2,411			
Code house	Current house if built to MNECCH with 60 cfm continuous heat recovery ventilation, standard furnace fan	$2,490	Plus $79	Expensive to upgrade exterior walls slightly; very impractical to insulate basement floor.	
Upgrade option 1 (current + venting)	60 cfm continuous non heat recovery ventilation, standard furnace fan	$2,902	Plus $491 from current house	Estimated $900 installed cost	None from current house
Upgrade option 2	60 cfm continuous heat recovery ventilation; ECM furnace fan motor; average annual mechanical + natural airchange rate .325 ac/h.	$2,905	Plus $184 from current house but $307 annual saving from non-heat recovery ventilation option	Estimated $2,300 installed cost	None from current house; installed cost difference from option 1 = $1,400 / $307 annual saving = 4.6 year payback

Commentary

If the house is maintained in the way that it has been to date, it should last 30 years or more. (The only question is the durability of the preserved wood foundation, depending on the construction detailing.) Continuous ventilation will enhance the durability of the building, as well as contribute to a healthy environment. The operating cost of non-heat recovery ventilation, distributed through the continuous operation of a standard furnace fan, is not cost-effective.

Table 5.2: House 4 Renovation Plan for Indoor Air Quality, Durability and Energy Efficiency	
No cost / lower cost recommendations	**Cost**
1. Clean up the slight mold on the basement bedroom window	$0
2. Restrict the access of the cat and dog throughout the house.	$0
3. Minimize the use of candles.	$0
4. Inventory the cleaning chemicals in the house and recycle those that are not necessary.	$0
5. Replace the dryer flexible duct with rigid aluminium duct.	$60
6. Replace the glass fibre furnace filter with an electrostatically charged pleated filter.	$22
7. Install the missing piece of aluminum fascia.	$60
8. Replace the chimney cap.	$0
Total	**$142**
Medium cost recommendations	
1. Airseal around the patio doors, furnace vent, electrical receptacles and light switches.	$120
2. Complete the insulating and airsealing of the accessible portions of the main floor frame perimeter.	$60
3. Install a pwf plywood cover on the above grade portion of the foundation wall dampproofing.	$720
Total	**$900**
Higher cost recommendations	
1. Install a heat recovery ventilator with a simplified duct system.	$1,500
2. Install an efficient, 2-speed furnace fan.	$800
3. Replace carpets, as they wear out, with hard surface flooring (no cost at this time).	$0
Total	**$2,300**
Total indoor air quality, durability and energy efficiency recommendation costs	**$3,342**
Conclusions Continuous heat recovery ventilation distributed through the existing forced air system with an energy efficient furnace fan will not cost any more to operate than the current house with no continuous ventilation. Following this renovation plan, at a total cost of $3,342, will help to ensure better indoor air quality and house durability. This house is a valuable asset in good condition. Considering its expected lifespan, this is a worthwhile investment.	

Chapter 6: House Investigation Number 5

Figure 10: House 5, original part, east side

Figure 11: House 5, addition, west side

The Occupant's Perspective

The band owns this house. It is essentially two 24 foot x 32 foot bungalows joined for 15 feet along one side. The original house was built around 1970. The new portion was added around 1990. One elderly woman, with failing sight, lives in this house. Her first language is Ojibwa.

Numerous people stay here for various lengths of time. Two other young adults apparently lived in the house at the time of this investigation. The occupant keeps extra mattresses and blankets to put on the floors for guests.

According to the home occupant, the plumbing freezes at times. The electricity has been disconnected for five years due to non-payment.

There are problems with ants and mice. There are birds in the attic. Smoking in the house is common. Indoor pets include several cats and possibly some dogs.

Site Observations May 17, 2000

Weather
Clear, sunny, slight breeze, 16C, RH 35%
Dry ground conditions

Limitations to the investigation
The crawl space under the older part of the house is very low and there is access only to one side.
The attic of the new part was inaccessible.

Exterior
Detached house on open site overlooking the lake
Slight slope to the northeast
Drainage toward the house on the southwest

Original house:
Concrete block crawl space foundation
Hardboard siding, in poor condition, penetrations, corners missing
Grade above first row of siding in places on north and south sides
Windows single glazed, wood frame plus storms, in poor condition, some broken or missing panes
Wood hollow core door, poor condition
Wood soffit and fascia, poor condition

Addition:
PWF piers with PWF plywood skirt under addition
Vinyl siding, some detached south side
Windows double-glazed in fair condition
Insulated steel door, poor condition, weatherstrip and lockset damaged – held closed by jamming a woollen mitt between the door and the door frame
Metal soffit and fascia
No air intakes
One bath fan exhaust, inoperable due to no electricity
No eavestroughs or downspouts
Medium slope asphalt shingle roof, fair condition
North side roof junction between original and addition probably leaks - valley flashing condition suspect, poor design
Soffit and gable vents
Interior prefabricated metal chimney
Old appliances, furniture, gas cans on deck
Deck railing broken, no stair railing
Debris, abandoned vehicles, broken glass around house

Attic
Original house attic accessible through ceiling hatch
Trusses at 2' on centre, R20 glass fibre batt insulation
Birds, mouse feces
Addition gable end hatch inaccessible

Foundation
T 15C, RH 60%

Original house:
Concrete block crawl space foundation for original house insulated on the inside with 2" extruded polystyrene
Floor insulated with R12 glass fibre batts held in place with hardboard between 2x8 joists

Mortar deteriorating
No vents
Some debris

Addition:
PWF piers with PWF plywood skirt under addition, not insulated
Floor insulated with glass fibre batts full depth of 2x8 joists, held in place with hardboard and strapping
Many holes under skirt
Damp, evidence of flooding
Ditch south to north, wet but no running water
Wet insulation under bathroom and northeast bedroom floor, sewer smell, no visible leak
Electric baseboard heater under bathroom area, essentially outside the house envelope, would be on constantly in winter (if electricity available)
Some debris

Mechanical systems
Space heating with wood box stove in dining area
Vertical chimney through ceiling, vent pipe clearances from wall suspect
Box stove door open to encourage draft – backdrafting likely
Chimney cleaning unlikely
Naptha fuelled Coleman stove for cooking on dining room table
Long extension cord through window from neighbouring shed provides some electricity
Community water supply – sometimes freezes
No hot water supply

Main level building envelope
Original house hardboard panelling, 2x4 walls, R12 glass fibre insulation assumed, sheathing, hardboard siding, ceiling insulated with R20 glass fibre batts
Addition hardboard panelling, 2x6 walls, R20 glass fibre insulation assumed, sheathing, vinyl siding, ceiling insulation inaccessible – R20 assumed
No airtightness test because no electricity and wood stove burning, airtightness level assumed to be very leaky

Kitchen/Dining
T 18C, RH 60%
Very musty odour, many flies
Vinyl tile flooring, dirty, poor condition, rotting
Hole in floor in front of kitchen cabinets
Hardboard panel walls, dirty, poor condition
Ceiling tiles, black soot stains, water stains
Windows single glazed with storms, missing panes, waterstains, peeling paint, rot
No visible plumbing leaks although occupant reports leak under sink
Box stove for heat
Coleman stove for cooking
Large open garbage
Very poor housekeeping

Bathroom
T 18C, RH 60%
Strong odour
Vinyl sheet flooring, dirty, poor condition
Hardboard panel walls, fair condition
Ceiling tiles, fair condition
No windows
No heating
No mechanical ventilation
Plumbing leaks apparent
Big box of garbage, used toilet paper
Cat excrement in bathtub and on floor
Poor housekeeping

Laundry area
T 18C, RH 60%
Vinyl tile flooring, dirty, poor condition, many missing tiles, cat excrement
Hardboard panel walls, poor condition
Ceiling tiles, black soot stains
Excessive storage – garbage, piles of clothing and blankets

Living room
T 18C, RH 60%
Vinyl sheet flooring, poor condition, missing sections
Hardboard panel walls, fair condition
Ceiling tiles, fair condition

Bedrooms
T 18C, RH 60%
Vinyl tile flooring, poor condition, many tiles missing
Northeast bedroom floor water stained along outside wall

Hardboard panel walls, fair condition
Ceiling tiles, water stains, some broken tiles

Storage room
Adjacent to dining area
Vinyl tile flooring, dirty, poor condition
Hardboard panel walls, fair condition
Ceiling tiles, poor condition
Excessive storage: furniture, garbage
Very strong odour

Indoor Air Quality Recommendations

Normally, lower cost, medium cost and higher cost recommendations would be offered. In this case, the elderly home occupant has health and financial difficulties and is obviously unable to maintain the house or to improve it.

The original part of the house contains the kitchen, dining area, storage room, one bedroom and the laundry area. Building envelope deficiencies include:

- Very low crawl space, difficult to renovate;
- Foundation concrete block mortar deteriorating;
- Grade above the first row of siding in some places;
- Siding, soffits, fascia, windows and doors in poor condition;
- Broken deck railing;
- Birds, mice in attic;
- Holes in rotting floor unsafe; and
- Poor floor, wall and ceiling finishes.

The addition contains the bathroom, living room and two bedrooms. Building envelope deficiencies include:

- PWF pier foundation with PWF plywood skirt with many holes, ditch running through crawl space;
- Main floor not fully insulated or airsealed from crawl space;
- Plumbing in un-insulated crawl space;
- Floor insulation wet under bathroom/bedroom area;
- Some vinyl siding detached;
- Roof junction between original and addition probably leaks;
- Door and frame in poor condition; and
- Poor floor, wall and ceiling finishes.

For both parts, mechanical system deficiencies include:

- Unsafe wood stove installation;
- Unsafe use of naptha Coleman stove for cooking;
- Unsafe electricity supply through long extension cords;
- Heating capacity insufficient for the size of the house;
- Poor heat circulation;
- Possible plumbing leaks in bathroom;
- Water supply freezes on occasion;
- No hot water supply; and
- No mechanical ventilation.

Health concerns include:

- Very poor housekeeping;
- Excessive garbage storage in storage room; and
- Pet excrement on floors and in bathtub.

For the original portion, repairs would be necessary for the:

- Foundation
- Floor
- Grading
- Insulation
- Siding
- Windows
- Door
- Interior finish
- Electrical
- Plumbing and
- Heating.

This could not be cost effective. Demolition of the original part seems justified.

If the original part were demolished, the addition would still require many repairs, including:

- Foundation at the joining wall
- Floor insulation and air sealing
- Grading
- Siding
- Roof

- Door
- Installation of a kitchen
- Interior finish and cleaning
- Electrical
- Plumbing
- Installation of a heating system

It seems likely that the home occupant would still have difficulty maintaining the renovated house. For any occupant, the value of the existing addition does not justify the input of capital to renovate it. The money would be better spent on a new house.

Energy Efficiency Commentary

For safety reasons, it would make sense to heat elders' housing electrically. In this house, if electricity were used for all space heating, domestic hot water, lights and appliances, the annual energy cost would be $3,516, according to a HOT-2000 analysis. Suitable row housing for elders, similar to the elders' housing already available at Washagamis Bay, would be inexpensive to build and maintain. A single row-housing unit could very easily have annual energy costs under $1,500.

From an energy efficiency perspective, as well as indoor air quality perspective, this house is not suitable for renovation.

The occupant of this house should be re-located. The house should be demolished before it burns; rots; or any more money is wasted on it.

Chapter 7: Trends

Table 7.1 Building specifications based on house age compared to the Model National Energy Code of Canada for Houses 1997 (MNECH) prescriptive requirements (for the range of fuel types)

Particulars	House 3	House 5 original	House 5 addition	House 1	House 4	House 2	MNECCH 1997
Year built	1970	1970	1990	1990	1994	1999	
Airchange rate @ 50 Pa	7.87 ac/h	10 45 ac/h assumed	10 45 ac/h assumed	6.81 ac/h	2.23 ac/h	2.80 ac/h	Continuous air barrier
Attic type roof	R24	R20	R20 assumed	R32	R40	R40	RSI 7 0-10 6 = R40-R60
Other roof	N/A	N/A	N/A	N/A	R40	N/A	RSI 4 3-7 1 = R24-R40
Above grade walls	R12	R12	R20	R20	R20	R20	RSI 3.3-4 7 = R19-R27
Main floor perimeter	R12	R12	R24	Un-insulated	R10	Un-insulated	Not included in wall requirements
Exposed floors (over unheated crawl space)	R12 (although crawl space currently unheated)	R12	R24	N/A	Second floor cantilever insulation undetermined	N/A	RSI 4 6-7 1 = R26-R40
Crawl space walls	R11, no air/vapour barrier	R10 although unheated	Un-insulated	R20, poor air/vapour barrier	Basement walls R28	R20, no air/vapour barrier	All are wholly or mainly above grade so R19-R27
Below grade (<0.6m) floors	Un-insulated, no moisture barrier, dirt	Un-insulated, no moisture barrier, dirt	Un-insulated, no moisture barrier, dirt	Un-insulated, no moisture barrier, dirt	Assumed un-insulated, concrete	Un-insulated, no moisture barrier, dirt	RSI 1.60 = R9 full floor area
Openable windows	Single or double glazed, clear, air fill, metal spacer, wood frame	Single glazed, wood frame	2 glazed, clear, air fill, metal spacer, wood frame	2 glazed, clear, air fill, metal spacer, wood frame	3 glazed, clear, air fill, metal spacer, wood frame	2 glazed, low E, argon fill, insulated edge spacer, vinyl frame	Minimum energy rating –10.0 to -13 0
Fixed windows	N/A	N/A	2 glazed, clear, metal spacer	2 glazed, clear, metal spacer	3 glazed, clear, metal spacer	2 glazed, low E, argon, insulated edge	Minimum energy rating –10.0 to –13.0
Heating	Central wood pellet stove, 1 electric baseboard heater	Central wood stove, electric baseboard heaters not functional	Heated with original area wood stove	Central wood pellet stove not used, electric baseboard htrs	Direct vent oil boiler	Central wood pellet stove	Prescriptive requirements based on fuel type
Air circulation	2 living room ceiling fans	None	None	Living room ceiling fan	Ducted forced air	Living room ceiling fan	NBCC 1995 requires circulation of ventilation air
Ventilation	Bathroom fan	None	Bathroom fan, not functional	Bathroom fan 15 cfm flow	3 bath fans, blocked fresh air supply	Bath fan, 25 cfm flow	Heat recovery ventilation

Table 7.2 Prescriptive Building Envelope Insulation Targets from Model National Energy Code for Houses for Ontario >=5000 DD

Space Heating Fuel	Electricity, Other	Propane, Oil, Heat Pump	Natural Gas
Attic type roof	RSI 10.60 (R60)	RSI 8.80 (R50)	RSI 7.00 (R40)
All other roofs	RSI 7.10 (R40)	RSI 4.30 (R24)	RSI 4.30 (R24)
Above Grade Walls	RSI 4.70 (R27)	RSI 4.10 (R23)	RSI 3.30 (R19)
Exposed Floors	RSI 7.10 (R40)	RSI 4.60 (R26)	RSI 4.60 (R26)
Walls in Contact with Ground	RSI 3.10 (R18)	RSI 3.10 (R18)	RSI 3.10 (R18)
Floors on Ground <0.6m Below Grade	RSI 1 60 (R9)	RSI 1 60 (R9)	RSI 1 60 (R9)
Operable or Fixed Glazing With Sash	ER -10 0	ER –13 0	ER –13 0
Heat Recovery Ventilation	Required	Required	Required

Table 7.3: Energy efficiency (EE) proposals, final recommendations and total renovation costs				
Particulars	**House 1**	**House 2**	**House 3**	**House 4**
Estimated current house annual energy cost	Annual cost $2,474 If ventilated: $2,528 If originally built to MNECCH: $1,848	Annual cost $1,978 If ventilated: $2,078 If originally built to MNECCH. $1,671	Annual cost: $2,259 If ventilated: $2,399 Older house, not compared to MNECCH	Annual cost: $2,411 If ventilated $2,902 If originally built to MNECCH: $2,490
1a Potential energy efficiency and ventilation renovations	Crawl space moisture barrier; airsealing to typical levels, R10 insulated main floor perimeter, 2' strip R10 footing insulation, better bathroom fan Cost: $1,896	Crawl space moisture barrier and wall sealing; other airsealing; R10 main floor perimeter insulation, 2' strip R10 footing insulation; 30 cfm continuous non-heat recovery ventilation Cost: $2,195	Crawl space moisture barrier, airsealing; storm or double glazed windows; 2' strip R10 footing insulation; 30 cfm continuous non-heat recovery ventilation Cost: $3,200	60 cfm continuous non-heat recovery ventilation Cost $900
1b Estimated annual energy cost of renovated house	Annual cost: $2,206 Annual saving: $268 Capital cost payback period. 7.1 years	Annual cost: $2,020 From current house: plus $42 No capital cost payback	Annual cost $2,168 Annual saving: $91 Capital cost payback period. 35 years	Annual cost: $2,902 Plus $491 from current house No payback
2a Upgraded renovation plan	As above, plus use wood pellet stove	Envelope renovations as above, ceiling R60, crawl space floor R10; 30 cfm continuous heat recovery ventilation Cost: $5,599	Building envelope renovations as above; 30 cfm continuous heat recovery ventilation Cost: $3,800	60 cfm continuous heat recovery ventilation & ECM furnace fan motor Cost: $2,300
2b Estimated annual energy cost of renovated house with heat recovery ventilation	HRV not recommended	Annual cost: $1,735 Annual saving: $243 Capital cost payback period: 23 years	Annual cost: $2,106 Annual saving: $153 Capital cost payback period: 24.8 years	Annual cost: $2,595 Plus $184 from current house No payback
2c Initial plan versus upgraded plan	Capital cost: $20 Annual energy cost: $2,083 Extra saving $123 Extra payback. 2 months	Capital cost difference $3404 Extra savings: $285 Extra capital cost payback: 11.9 years	Capital cost difference $600 Energy savings $62 HRV capital cost payback: 9.7 years	Capital cost difference: $1400 Energy savings: $307 HRV capital cost payback: 4.6 years
3a Final renovation plan	Building & ventilation renovations as above, train occupant in use of pellet stove (to accomplish 75% of space heating)	Renovations & HRV as above: this house is deteriorating quickly; the renovations will save the capital already invested & provide a healthier living environment for less annual energy cost.	Crawl space floor moisture barrier; CO detector; fix any roof & plumbing leaks; re-connect crawl space heater; replace damaged bathroom finish, caulk around windows and doors; plastic storms annually; manually re-grade; re-attach siding; fix gable vents	Dryer duct; furnace filter; fascia repair; modest airsealing; damp-proofing cover; HRV, efficient furnace fan
3b Estimated annual energy cost of proposed house	Annual cost: $2,083 Annual saving: $391 Capital cost payback period: 4 9 years Saving if current house ventilated: $445 Payback period from ventilated house: 4.3 yrs	Annual cost: $1,735 Saving from current house: $243 Capital cost payback period: 24 7 years Saving if current house ventilated: $343 Payback. 17.5 years		As described above, there is no payback from the current house but there would be a 4 6 year payback if the current house were ventilated and compared to the proposed renovation.
4a Total IAQ, durability, energy efficiency and damage repair renovation costs	Capital cost: $9,996 Capital cost payback period: 9,996 / 391 = 25 6 years (or 9,996 / 445 = 22.5 years)	Capital cost: $8,584 Capital cost payback period: 8,584 / 243 = 35 3 years (or 8,584 / 343 = 25.0 years)	Capital cost $1,345 Capital cost payback period: none	Capital cost: $3,342 Capital cost payback period: none (or 10 9 years from ventilated house)
Notes (As stated previously, any renovation of House 5 is not recommended)	Many costs are not IAQ or energy efficiency upgrades but repair of faulty original construction and damage Cost recovery through energy savings has a very long payback but extended building lifespan is expected.	Upgrades will increase energy efficiency, indoor air quality and durability to save capital already invested, increase building lifespan and provide a healthier environment Cost recovery is very long	Annual energy cost is the same or slightly lower than current; upgrades for short-term only; replacement house recommended	Annual energy cost $184 higher than current unventilated house, cost effective if compared to equivalent non-heat recovery ventilation Upgrades will increase durability and provide a healthier environment

Table 7.4: A comparison of renovation plans					
Lower or no cost recommendations	**House 1**	**House 2**	**House 3**	**House 4**	**House 5**
Install a carbon monoxide detector in the main living area.		Yes	Yes		Almost all of the lower or no cost options would apply. Use of this house is no longer advised.
Discourage everyone from smoking in the house.	Yes	Yes	Yes		
Clean up small areas of mold.	Yes	Yes	Yes	Yes	
Minimize the use of candles.				Yes	
Investigate and repair the source of the kitchen ceiling water leak.			Yes		
Fix plumbing drain leaks.		Yes			
Check the water supply line valve in the crawl space for leaks			Yes		
Conduct a thorough 'spring cleaning'.	Yes				
Keep kitchen garbage in a smaller, covered container. Empty daily.	Yes	Yes	Yes		
Set mousetraps continuously.	Yes		Yes		
Restrict the access of pets throughout the house.			Yes	Yes	
Clean the debris out of the crawl space.	Yes	Yes	Yes		
Check the refrigerator defrost pan for leaks.	Yes				
Inventory the cleaning chemicals in the house and discard those that are not necessary.	Yes	Yes	Yes	Yes	
Clean the bathroom exhaust fan (for use until the HRV is installed).	Yes				
Replace the flexible, plastic bathroom exhaust duct with rigid duct.		Yes			
Vent the dryer outside through rigid, aluminium duct		Yes		Yes	
Use the bathroom fan and ceiling re-circulating fan frequently.			Yes		
Re-connect the crawl space electric heater.			Yes		
Re-connect the eaves-trough downspouts.			Yes		
Move the child's bed away from the electrical panel.	Yes				
Install a plastic dam at the head of the bath-tub.	Yes	Yes	Yes		
Train the home occupants in the use of the pellet stove.	Yes				
Repair the electric heaters, light fixtures and receptacle cover plates.	Yes				
Install more hangers on the crawl space plumbing drain lines.	Yes				
Undercut all interior doors (or leave them open as much as possible).		Yes			
Minimize the plants in the house.		Yes			
Move the materials piled against the house.			Yes		
Upgrade the furnace filter.				Yes	
Replace the chimney cap.				Yes	
Medium cost recommendations	**House 1**	**House 2**	**House 3**	**House 4**	**House 5**
Relocate the pellet stove sidewall vent not less than 4 feet horizontally from the window.	Yes	Yes			Many of the medium cost options would apply. None are advised.
Replace the wall finish behind the toilet.			Yes		
Install a sealed moisture barrier over the crawl space dirt floor.	Yes	Yes	Yes		
Install a sealed air/vapour barrier at the ceiling penetrations.	Yes				
Re-insulate and re-install the crawl space wall air/vapour barrier.	Yes	Yes			
Replace the crawl space access door.	Yes				
Insulate and seal the perimeter of the main floor framing.	Yes	Yes		Yes	
Airseal the main living area (+ caulking around doors and windows).	Yes	Yes	Yes	Yes	
Install a better bathroom fan	Yes				
Re-attach loose siding; install missing fascia.		Yes	Yes		
Install screens on operable windows.	Yes				
Install eavestroughs and downspout extensions.	Yes	Yes			
Re-install the water heater on a solid base.		Yes			
Install a gable end attic access door.	Yes				
Straighten and screen gable end vents.			Yes		
Install closet rods and shelves.	Yes				
Re-grade manually.			Yes		
Install a pwf cover over above grade foundation wall dampproofing.	Yes	Yes		Yes	
Higher cost recommendations	**House 1**	**House 2**	**House 3**	**House 4**	**House 5**
Excavate and damp-proof the foundation.	Yes	Yes	No higher cost options are advised		No higher cost options are advised
Install foundation perimeter drainage.	Yes	Yes			
Install footing insulation.	Yes	Yes			
Backfill and slope grade away from the house.	Yes	Yes			
Upgrade ceiling insulation and crawl space floor insulation.		Yes			
Install a heat recovery ventilator.		Yes		Yes	
Stain the exterior.	Yes				
Replace the porches.	Yes				
Repair the interior damage.	Yes				
Replace the crawl space drywall with cement board.		Yes			
Replace carpets, as they wear out, with hard surface flooring.				Yes	

Chapter 8: Making Sense of the Situation

Current Construction Practices

According to the small sample of houses studied, current construction practices have led to unnecessary energy costs, poor indoor air quality and premature building failure. These practices include the following:

PWF walls are built directly on concrete footings, with no capillary break, in houses 1 (1990) and 2 (1999), and probably 4 (1994). Water wicks up from the soil, through the footings and into the wall framing and glass fibre insulation. Mold growth and premature failure are strong possibilities.

No perimeter drainage was installed in houses 1, 2, 3 (1970) and 5 (1970). At some times of the year, water runs through the crawl spaces of houses 2 and 5.

Un-insulated footings are exposed above grade in houses 1, 2 and 3. These houses were never properly damp-proofed or backfilled. This is a continuing energy cost and, depending on soil conditions, could result in frost heaving.

Uncovered dirt floor crawl spaces are present in houses 1, 2, 3 and 5. Dirt floors are huge sources of water vapour as well as major contributors to heat loss.

Poor crawl space air/vapour barriers are present in houses 1, 2 and 3. In house 1, the a/v barrier was applied but hangs loosely with many gaps. House 2, which is newest, has 4 feet wide strips of poly scattered on the crawl space floor but never applied to the walls.

Main floor air/vapour barriers are incomplete, although airtightness levels have improved over the years. Houses 1 and 2 both have large holes in the ceiling a/v barrier in closets.

There is poor exhaust of moisture and pollutants. Most bathroom fans are poorly ducted and provide little airflow. There are no outside exhausting range hoods. The dryer vent in house 2 terminates in the crawl space, adding to the moisture load.

The ventilation systems do not provide a good supply of fresh air. The only mechanical ventilation (except for the blocked fresh air supply duct in house 4) consists of bathroom exhaust fans.

Air circulation is insufficient. Ceiling fans provide the only air circulation in houses 1, 2 and 3. House 4 is the only one with forced air heat distribution. Without electricity, house 5 has no mechanical ventilation or air circulation. The lack of ventilation and air circulation in house 2 has contributed to mold growth in cold bedrooms.

Plumbing systems are not tested before house occupancy. The plumbing drain in house 2 has a joint that was never glued, resulting in wastewater leaking down the drywall of the party wall between duplex units. The drywall is moldy.

None of the houses meets the prescriptive requirements of the National Building Code of Canada 1995 or the Model National Energy Code of Canada for Houses 1997. Even the best house, house 4, does not meet the mechanical ventilation specifications of either code.

Can Energy Savings Recover Increased Capital Costs?

The costs for premature replacement of houses due to poor durability and the costs associated with poor indoor air quality are difficult to calculate. Energy efficiency analysis similar to the Energuide for Houses protocol permits calculation of energy cost savings and capital cost payback periods.

Cost effectiveness of the energy efficiency recommendations depends on the condition of the current house and the validity of the comparison being made. Fair comparisons can only be made using equivalent average annual natural plus mechanical ventilation rates. Adding non-heat recovery ventilation to current houses would increase their energy costs. On that basis, the payback periods for the proposed energy efficiency renovations are reduced.

The time periods that it would take for energy cost savings to recoup the expense of implementing energy efficiency measures as described in the final renovation plans are as follows:

House 1
Capital cost of proposed energy efficiency renovations: $1,896
Payback period: 8.1 years
Payback period at a similar total airchange rate: 7.0 years

House 2
Capital cost of proposed energy efficiency renovations: $5,599
Payback period: 23.1 years
Payback period at a similar total airchange rate: 16.3 years

House 3: Only minor renovations are recommended to ensure reasonable durability and comfort until this house can be replaced.

House 4: Cost of proposed ventilation: $2,300
Annual energy costs $184 higher than current house, no payback
Payback period at a similar total airchange rate: 4.6 years

House 5
Re-location of the occupant and demolition of the house are recommended.

Conclusions

In the first house, energy savings would pay back the invested capital within a reasonable period of time. In the second house, which has a better building envelope already, savings will take longer to recoup. In the fourth house, providing continuous heat recovery ventilation efficiently will increase annual energy costs.

In all three of these houses, the proposed renovations should provide improved indoor air quality and a longer expected building lifespan.

The Renovation Plans

Many of the recommendations made are not only related to indoor air quality or energy efficiency. Drainage, finish of incomplete houses, safety, durability and damage repairs must be addressed. All of these problems have added major costs to the proposed final renovation plans, sharply reducing the ability of energy cost savings to pay back the renovation capital costs within a reasonable time period. The total renovation costs are estimated as follows:

House 1
Total proposed renovation costs: $9,996
Payback period due to lower energy costs: 25.6 years
Payback period if calculated at similar total airchange rates: 22.5 years

House 2
Total proposed renovation costs: $8,584
Payback period due to lower energy costs: 35.3 years
Payback period if calculated at similar total airchange rates: 25.0 years

House 3
Total proposed renovation costs: $1,345
Minor energy cost savings

House 4
Total proposed renovation costs: $3,342
Energy consumption $184 higher
No payback from current house
Payback period if calculated at similar total airchange rates: 10.9 years

The total cost for renovations proposed in this report is $23,267. In addition, House 5 should be replaced as soon as possible and House 3 should be replaced when funding is available.

Energy cost savings can provide some payback but they cannot completely finance renovations that must be done for deficiencies unrelated to energy consumption. The most important reasons to renovate houses deficient in other areas are to save the capital already invested and provide a healthier living environment for the occupants.

The Potential for Cost Effective Improved Housing

The Indoor Air Quality Recommendations

Home occupants can help. Most home occupants could implement at least half of the no cost or lower cost recommendations. This is definitely cost effective.

Houses built or renovated to provide better indoor air quality will also provide better durability and energy efficiency. Almost all medium cost and higher cost IAQ recommendations also improve energy efficiency and building durability by providing:

- drainage for less moisture loading;
- airtightness for better control of the indoor environment;
- insulation for warmer surfaces; and
- heat recovery ventilation as opposed to non-heat recovery ventilation.

Recommendations for these three purposes are compatible.

Energy Efficiency Recommendations

Build to the prescriptive requirements of the Model National Energy Code of Canada for Houses 1997. If house 2 (built in 1999) had been built to MNECCH 1997 specifications, including heat recovery ventilation, energy costs would be lower than for the current unventilated house.

Airseal appropriately. The two newest houses, 2 and 4, are reasonably airtight so airtightness improvements would make little difference to energy efficiency. House 1, only 10 years old, could benefit from airtightness improvements.

Evaluate first to find the most cost-effective insulation upgrades. Insulation values have increased over 30 years so the difficulty of insulation improvement in the main wall areas of newer houses is often not worth the cost or disruption. Less disruptive, cost effective improvements can be made through footing insulation skirts, main floor perimeter insulating, crawl space floor insulation or upgraded ceiling insulation.

Installation of wood pellet stoves should be re-considered. It first seems that occupants can save $300 to $400 per year by heating with wood pellets instead of electricity. However fan operation and stove maintenance reduce savings. The occupants must know how to operate the stoves, as well as store and handle from about 90 to 200 40-pound bags of pellets annually.

Depending on the energy efficiency of the building, the estimated $2,300 installation cost may take 11 to 18 years to recover through energy savings. Sidewall venting for two of the three stoves was not installed according to the manufacturer's specifications

Without a whole house ventilation system, there is no opportunity to heat the crawl spaces with these stoves or to effectively circulate the heat to the bedrooms.

Since the pellet stoves are already installed, they might as well be used but capital costs for future installations would be better spent on building envelope and ventilation improvements.

Start with simple solutions. Because of the need to maintain simplicity in the recommendations, the use of energy efficient lighting or more complex integrated space heating systems has not been explored.

Effective Use of Capital

The first purpose of this report was to prove that less capital investment in First Nations housing but acceptance of higher energy costs incurred over the life cycle of a house is not cost-effective. It quickly became apparent that it is not only less capital investment but also the ineffective use of the available capital that has resulted in housing problems.

Better specifications and increased capital expenditure would have been required at the time of construction to provide improved heating, ventilating and building envelope insulation values. However, other deficiencies, such as lack of drainage, no crawl space floor moisture barriers, poor air/vapour barriers, leaky plumbing and dryers that vent into crawl spaces could have been completed properly during construction for little extra cost.

House 4 is a much larger and more expensive house than the others that were investigated. Two other new houses were also under construction and 'closed in' at the time that these five house investigations were taking place, yet the foundation of house 2, built in 1999, was still not finished.

The decision-making process used in the allocation of funding and allocation of housing is unclear. This is a subject beyond the scope of this project.

Chapter 9: General Recommendations and Conclusions

General Recommendations for Effective Renovation and New Construction Planning

The following general recommendations are based on the indoor air quality and energy efficiency investigations of the five houses selected as a representative sample by the Housing Director of the Washagamis Bay First Nation. This is a small sample so there is no doubt that some suggested actions will be inappropriate or already underway in other houses and communities:

Develop greater First Nations capacity in IAQ and energy efficiency evaluations. The indoor air quality and energy efficiency evaluations done on these houses according to these two protocols have resulted in many recommendations. The equipment and training required to become proficient in these evaluation methods is available at reasonable cost. Sufficient First Nations capacity in these evaluation methods could be developed.

Regional First Nations housing inspection agencies could be trained and equipped to provide IAQ and energy efficiency evaluations. It is not cost effective nor is there likely to be continuity of service or standards if these inspections are offered on a single community basis in small communities.

Inventory the existing houses. Keep a database that can be periodically updated by recording renovations, repairs and events (such as flooding, leaks, and so on). This inventory can be created by using three tools:

- A simple specification checklist that will provide a record of the building structure and mechanical systems;
- An indoor air quality investigation according to the CMHC IAQ Investigative Protocol;
- An energy evaluation according to the Energuide for Houses protocol.

The first checklist will be the least expensive, requiring less time for each inspection and less training for the inspector. This is the information needed for a fundamental database.

The second investigation is more time consuming and requires more training on the part of the investigator.

Following the Energuide for Houses protocol also requires some training and some investment in equipment, most notably a blower door (under $3,000).

Use the information from these investigations to make renovation decisions. Some decisions could be based strictly on durability issues that could be identified through the use of the specification checklist.

More useful information would become available through the use of the IAQ and energy efficiency protocols.

Energy efficiency improvements could be evaluated through the calculation of estimated payback periods.

For new construction or renovations, use standard house specifications and inspect houses to ensure that standards are being met. The safety and durability issues confronted during these investigations also point to a need for a more basic specification and inspection protocol, both during construction and before renovation. Many indoor air quality and energy efficiency issues could be avoided by building, renovating and inspecting according to simple specifications that meet the prescriptive standards of the National Building Code of Canada 1995 and the Model National Energy Code of Canada for Houses 1997.

Pre-occupancy inspections based on these specifications could be used as a basis of payment to contractors.

When building new houses, finish them completely. Weather and community pressure for houses to be quickly ready for occupancy are continuing problems. However, not finishing items like dampproofing, drainage, grading, moisture and air/vapour barriers, and dryer venting only leads to decreased building lifespan and unhealthy living conditions.

Build frost-protected slab on grade foundations, rather than preserved wood crawl space foundations, whenever possible.

Encourage and train home occupants to take ownership of minor problems. Use the information available in pamphlets such as the CMHC *First Nations Occupants Guide to Mold*. In some situations, such as house #5, occupied by an elder in poor health, expecting the occupant to solve the problems is unrealistic. The house is unsuitable for the occupant. In other cases, such as house #4, the occupant has the skills and initiative to not only maintain the house so that it is immaculate, but to renovate so that the house is more valuable and more durable than when first occupied.

Suggestions for Further Research

Continue the development of standard house specifications and inspection procedures. The original specifications for the construction of houses 1, 2 and 4, built in the 1990's, seem to vary considerably. None of them match the prescriptive standards of the National Building Code of Canada 1995 or the Model National Energy Code of Canada for Houses 1997. Suitable specifications for each housing component could be developed, using those standards as a guide. These specifications could be used for house construction, renovation and inspection.

Renovate these houses as a pilot project. Comprehensive renovation plans for three houses have been presented in this report. Total renovation costs have been estimated at $23,187 (not including replacement of house 5). These costs have been reviewed and approved by the resource coordinator of the Washagamis Bay First Nation.

These renovations could be carried out, using specifications as outlined above. Costs could be recorded. A second indoor air quality and energy evaluation of each house could be undertaken on-site after renovation. Analysis of the data could reveal the degree of success attained and any shortcomings in evaluation methods, cost estimates or on-site completion of the work as specified. Recommendations designed to help ensure the success of future renovation projects could be developed.

Compare housing funding to the houses created. This project concentrated on 5 individual houses. The last house built in 1999 is no more durable than the houses built in 1970. Two new houses were under construction in 2000 although the house built in 1999 is not complete. Unfinished and built to an inappropriate standard, the 1999 house will either have to be renovated soon or replaced prematurely. How housing funding is prioritized is unclear.

Allocation of housing funding in a community over a particular time period could be matched to the state of the housing that was created or renovated as a result of that spending. Analysis could determine what successes or failures exist. Recommendations could be developed to allow future spending to be more cost effective.

Conclusions

In this small sample, the house built in 1999 is no more durable nor does it provide better indoor air quality than the houses built from 1970 to 1990.

The renovations proposed in this project will enhance indoor air quality, energy efficiency and durability of the houses.

Capital costs can often be recovered through energy savings but payback periods may be long. Improving house durability and indoor air quality are more important. Some houses are beyond repair and should be replaced.

Houses are not being built to nationally accepted standards nor are they being completed. Some of the renovation costs are for items that should have been completed during the original construction.

Building to the prescriptive standards of the National Building Code of Canada 1995 and the Model National Energy Code of Canada for Houses 1997 would provide houses with better indoor air quality, increased durability and lower energy consumption costs.

Completely upgrading existing houses to these specifications is impractical. However, some upgrades, using these standards as a guide, are often cost effective.

In newer, tighter houses that are still in good condition, adequate drainage and appropriate ventilation can reduce moisture loading, protecting the capital already invested while providing better indoor air quality.

Two simple, repeatable protocols have been used to evaluate these houses. From this small sample, it seems that an even simpler checklist would identify many of the safety, durability and health issues affecting these houses.

With a modest amount of training and equipment, First Nations technical service providers could use all three protocols to enable communities to make cost effective renovation and new construction decisions.

This project has made no attempt to determine if the housing budget in this community is sufficient. Nor has there been any attempt to determine the costs associated with premature building failure or poor living conditions. However, by using the CMHC IAQ Investigative Protocol and an energy analysis similar to the Energuide for Houses system, it is clear that recommendations can be developed so that energy cost savings could help to offset the capital costs of new or renovated houses that would last longer while providing better indoor air quality.

Endnotes

[1] Ark Research Associates, *The Housing Conditions of Aboriginal People in Canada, 1991*, a research report prepared for Canada Mortgage and Housing Corporation, Autumn 1996, Executive Summary.

[2] Boles Construction, *A Study of Recurring Mold Problems on the Roseau River Reserve, Manitoba*, a research report prepared for CMHC, 1998, p. 54.

[3] Sherwood Industries Ltd, *Enviro Fire Installation Manual*, revised April 1994, p.10. This information confirmed July 4, 2000, by Barbara Bailie, customer service representative at The Foundry, the Ontario distributor for the Enviro line of stoves and by Graham Copeland, a technical service representative at Sherwood Industries Ltd.

[4] National Research Council of Canada, *National Building Code of Canada (NBCC) 1995*, p.221.

[5] Natural Resources Canada, *HOT2000 version 8.*

[6] National Research Council of Canada, *Model National Energy Code of Canada for Houses 1997*, p.67-68.

[7] The energy efficiency of recommendations has been calculated similarly, although not identically, to the protocol used in the Energuide for Houses Program. Differences include:

- HOT2000 rather than HOT2XP energy analysis software was used to allow greater flexibility.
- The total airchange rate of "this house ventilated" was set to be equal to a typical new house ventilated continuously at 30 cfm (40% of the recommended CSA F326 total ventilation capacity – a reasonably realistic model).
- The Energuide for Houses version of HOT2XP will automatically add non-heat recovery mechanical ventilation to any house that falls below an average monthly total airchange rate (natural plus mechanical) of .35 airchanges per hour. Using HOT2000, just enough mechanical ventilation was added to any "ventilated current house" scenario to create the same total airchange rate and enable fair comparisons.

[8] From a conversation with Graham Copeland, technical service representative, Sherwood Industries Ltd., January 24, 2001.

[9] HOT2000 modelling was done for electric baseboard heat. The space heating energy consumption was considered to be 25% electricity and 75% wood pellets. The space heating energy consumption attributable to wood pellets was de-rated at the stove manufacturer's efficiency rating of 83%, converted to tons of pellets (4689 kwh or 8,000 Btu/lb according to Barbara Baillie, Ontario Envirofiredistributor) and the fuel cost calculated at the rate of $190 per ton (50 bags).

[10] *NBCC*, p.214.

[11] This is an estimate arrived at through a conversation with Keith Wilson, a technical advisor with Owens Corning.