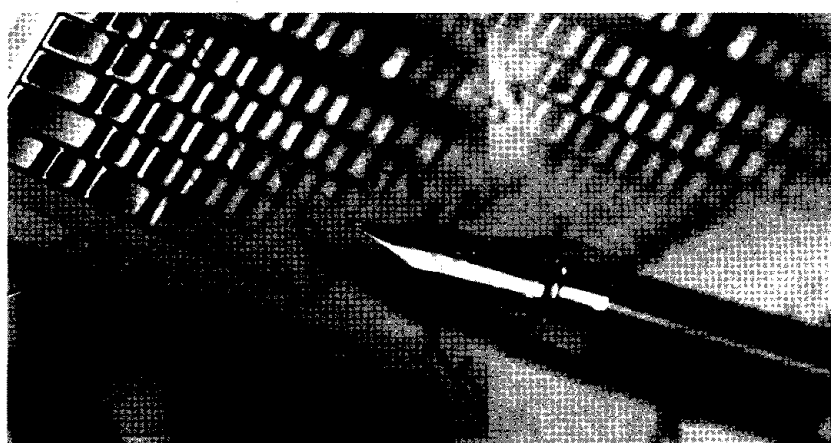




RESEARCH REPORT

HEALTHY HOUSING IN THE NORTH
TOWARDS A NORTHERN HEALTHY HOUSE

DEMONSTRATION PROJECT



HOME TO CANADIANS
Canada

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) is the Government of Canada's national housing agency. We help Canadians gain access to a wide choice of quality, affordable homes.

Our mortgage loan insurance program has helped many Canadians realize their dream of owning a home. We provide financial assistance to help Canadians most in need to gain access to safe, affordable housing. Through our research, we encourage innovation in housing design and technology, community planning, housing choice and finance. We also work in partnership with industry and other Team Canada members to sell Canadian products and expertise in foreign markets, thereby creating jobs for Canadians here at home.

We offer a wide variety of information products to consumers and the housing industry to help them make informed purchasing and business decisions. With Canada's most comprehensive selection of information about housing and homes, we are Canada's largest publisher of housing information.

In everything that we do, we are helping to improve the quality of life for Canadians in communities across this country. We are helping Canadians live in safe, secure homes. CMHC is home to Canadians.

Canadians can easily access our information through retail outlets and CMHC's regional offices.

You can also reach us by phone at 1 800 668-2642
(outside Canada call (613) 748-2003)
By fax at 1 800 245-9274
(outside Canada (613) 748-2016)

To reach us online, visit our home page at www.cmhc-schl.gc.ca

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1 800 668-2642.

Healthy Housing in the North
Towards a Northern Healthy House
Demonstration Project

Credits

Coordination by:

Stephen Fancott

Written by:

Bob Bromley
Ecology North

Stephen Fancott
Stephen Fancott Architect

Bill Fandrick
Synergy Solutions

Gino Pin
Pin/Matthews Architects

Additional writing and editing by:

Donna Diakun

Graphics by:

Dawn Clarke
Pin/Matthews Architects

Project Manager for CMHC:

Aleta Fowler
Northern Housing Researcher CMHC

Project Manager for Arctic Energy Alliance:

Rob Marshall
Executive Director AEA

Table of Contents

Introduction	1
Part One: Conditions and Concepts.....	5
1. Land and People	5
1.1. Introduction: The Environmental Imperative.....	5
1.2. Physical Environment.....	7
1.2.1 Physiographic Regions.....	7
1.2.2 Ecozones.....	7
1.2.3 Climate	8
1.3. Planning Environment	15
1.3.1 Introduction: Northern Aspects.....	15
1.3.2 Expectations.....	17
1.3.3 Characteristics of the Population.....	17
1.3.4 Housing and Change.....	19
1.3.5 Localization	20
1.3.6 Participatory Planning.....	20
1.3.7 Neighbourhood.....	23
1.3.8 Tenure	24
1.3. Summary List	25
1.3.9 Physiographic, Climatic and Environmental Factors ..	25
1.3.10 Water Body (coast, river, lake): Marine, Riverine, Lacustrine Locations	26
1.3.11 Latitude.....	26
1.3.12 Modes of Access	26
1.3.13 Sociophysical Infrastructure	26
2. Economics: Ecological Sustainability, Socioeconomics and Full Cost Accounting	29
2.1. Introduction: Ecologically Sustainable Building	29
2.2. Economic Analysis	29
2.2.1 Life Cycle Analysis	29
2.2.2 Embodied Energy.....	30
2.2.3 Full Cost Accounting.....	31
2.2.4 Affordability.....	31
2.3. Transportation	34
2.3.1 Local Materials	35
2.3.2 Local Energy	35
2.3.3 Existing Materials	35
2.3.4 Regional Sources	36
2.3.5 Railroad and Barge	36
2.3.6 Transportation Schedule	37
2.4. Fuel and Energy	38
2.5. Regulations and Policy.....	40
2.5.1 National Standards.....	41
2.5.2 Community Standards.....	42

2.5.3	Water Regulations	43
2.5.4	Power Regulations	44
2.5.5	Heating Regulations	45
2.5.6	Area Development	46
2.5.7	Site Development	47
2.5.8	Remote Buildings	48
Part Two: Technology and Information Resources		49
3.	Materials and Technology	49
3.1.	Introduction: Integrated Approach	49
3.2.	Site Design	50
3.2.1	Site Conditions	51
3.2.2	Building Orientation	51
3.3.	Materials	51
3.3.1	Builders' Reference	52
3.3.2	Selection Criteria	52
3.3.3	Material Categories	53
3.4.	Building Envelope	58
3.4.1	Envelope Design	58
3.5.	Building Systems	61
3.5.1	Building System Design	61
3.6.	Water Conservation	64
3.6.1	Water Conservation Design	64
3.7.	Indoor Air Quality	65
3.7.1	Air Quality Design	65
3.7.2	Air Handling	66
4.	Resources	67
4.1.	Sustainability and Socioeconomics	67
4.2.	Electronic Guides and Databases	68
4.2.1	Interactive Guides	68
4.2.2	Materials Databases	70
4.2.3	Web Resources	71
4.3.	Printed Guides and Databases	72
4.3.1	Material and Design	72
4.3.2	Community Development	73
4.3.3	Checklists	74
4.3.4	Energy and Equipment	74
4.3.5	Funding	75

Executive Summary

Healthy Housing in the North: Towards a Northern Healthy House Demonstration Project

This study is a review of the principles and technical information that can influence the realization of healthy and more sustainable housing in the North. The objective of this study is to begin addressing and enhancing the ecological sustainability, social appropriateness, and total (real) economic aspects of northern housing. The approach is to develop the concept of the Healthy House in a northern context.

People who design and construct housing in the North need to become more conscious of their impact on the environment, social structures and energy use. High environmental and dollar costs of fossil fuel energy in the North demand reconsideration of conventional building design, materials and technical systems. The need for repairing and reinforcing the social fabric calls for appropriate environmental and cultural design to create healthy and locally supported, self-sufficient northern communities. This study reviews and examines influences, aspirations, limitations and potential technical options for increasing sustainability in northern housing.

The study is divided into two parts. Part One is an overview of the northern context, ecological sustainability, social appropriateness, and total (real) economic aspects of northern housing. Part Two is a review of technical options and information resources.

Part One: Conditions and Concepts

Section One: Land and People

The Environmental Imperative

- At current rates of consumption, humanity is living unsustainably on the earth. The conservation and management of the earth's resources and ecosystems are imperative to sustaining human activity on the earth.

The Physical Environment

The physical environment has implications for:

- compatibility of housing with the natural environment, permafrost and wildlife
- heating load requirements, as measured by annual degree days
- building orientation to maximize the unique northern conditions of a low sun angle and seasonally increased solar gain
- availability of renewable energy sources, building materials and abundant fresh water

The Planning Environment

- The sparse population of the North is also highly diversified and specialized; therefore a participatory planning process can empower local communities and better meet their social and cultural needs.
- Strategies of ecological sustainability and effective planning need to be applied not only at the levels of the region and neighbourhood, but right down to the level of the specific site, applying appropriate materials and systems.

Section Two: Economics and Policy

Economics: Ecological Sustainability, Socioeconomics and Full Cost Accounting

- High transportation costs, great distances for transport, and extremes of climate make the need for energy efficiency, renewable energy and local building material sources even greater in the North than in other parts of Canada.
- The sustainable building assessment tools of Life Cycle Analysis (LCA), embodied energy and Full Cost Accounting (FCA) should be applied to four general areas of practice: transportation, building materials, fuel, and operations and maintenance.
- Site selection needs to consider climate change and permafrost retreat. Sites where the substrate has a high water content should be avoided.

Regulations and Policy

- Planning standards and regulations for building and financing housing need to become more flexible, in order to encourage the adoption of innovative servicing systems, financial structures and options for tenure.
- Policy changes to encourage ecologically sustainable building are recommended with respect to water, power, heating area development, site development and remote buildings.

Part Two: Technology and Information

Section Three: Materials and Technology

- Because of the great pressure that humans are placing on the earth's resources, there is a growing need to change the approach to design, construction and operation of housing, adding environmental performance as a new value. This section presents technology choices that are

resource-efficient and create a healthy, comfortable, non-hazardous space for occupants.

Section Four: Information Resources

- Resources that are useful towards building a northern sustainable Healthy House are listed in this section.

Significance and Implications

Ultimately, this study and its guidelines are intended to contribute to northern housing that is more ecologically sustainable and locally and socially appropriate during construction, in operation and at the end of service.

Résumé

La maison saine dans le Nord :

Vers un projet de démonstration de maison saine dans le Nord

Cette étude est un survol des principes et des données techniques pouvant influencer la production de logements sains et durables dans le Nord. L'objectif est de commencer à aborder et améliorer la durabilité écologique, la convenance sociale et, dans leur globalité, les éléments économiques (réels) du logement dans les régions nordiques. La démarche consiste à élaborer le concept de la maison saine dans un contexte nordique.

Ceux qui conçoivent et construisent des habitations dans le Nord doivent se sensibiliser à leur effet sur l'environnement, les structures sociales et la consommation d'énergie. Le coût écologique et financier élevé des combustibles fossiles dans le Nord oblige à repenser les démarches traditionnelles en matière de conception des habitations, de matériaux et de systèmes techniques. La nécessité de réparer et de renforcer le tissu social impose une conception adaptée sur le plan écologique et social afin de créer dans le Nord des collectivités saines et autonomes avec des assises locales. L'étude examine les influences, les aspirations, les limites et les choix techniques possibles pour accroître la durabilité des habitations dans le Nord.

L'étude se divise en deux parties. La Partie un est un aperçu du contexte nordique, de la durabilité écologique, de la convenance sociale et de la globalité des éléments économiques (réels) du logement dans les régions nordiques. La Partie deux traite des choix techniques et des sources d'information.

Partie un : Conditions et concepts

Section un : Les gens et la terre

L'impératif environnemental

- Aux taux actuels de consommation, l'humanité vit sur terre d'une manière non durable. La conservation et la gestion des ressources de la terre et des écosystèmes sont essentielles au maintien de l'activité humaine sur cette planète.

L'environnement physique

L'environnement physique a des incidences sur :

- la compatibilité des habitations avec le milieu naturel, le pergélisol et la faune
- les besoins en chauffage, mesurés en degrés-jours annuels
- l'orientation des bâtiments pour maximiser les conditions particulières au Nord, soit un faible angle solaire et un gain solaire accru de façon saisonnière
- l'existence de sources d'énergie renouvelable, de matériaux de construction et d'une abondance d'eau douce

Le cadre de planification

- La population clairsemée du Nord est également très diversifiée et spécialisée; une planification participative peut donc responsabiliser les collectivités locales et répondre mieux à leurs besoins sociaux et culturels.
- Les stratégies de durabilité écologique et de planification efficace doivent être appliquées non seulement au palier de la région et du quartier, mais jusqu'au niveau de chaque emplacement, en faisant appel à des matériaux et à des systèmes appropriés.

Section deux : Économie et politiques

Économie : durabilité écologique, facteurs socio-économiques et comptabilisation du coût complet

- Le coût élevé du transport, les longues distances pour le transport et les variations climatiques extrêmes rendent encore plus aiguë dans le Nord que dans les autres parties du Canada la nécessité de l'efficacité énergétique, de l'énergie renouvelable et des sources locales de matériaux de construction.
- Les outils d'évaluation de la durabilité de la construction que sont l'analyse du cycle de vie, l'énergie intrinsèque et la comptabilisation du coût complet devraient être appliqués aux quatre grands domaines de la pratique : le transport, les matériaux de construction, le combustible, et le fonctionnement et l'entretien.
- La sélection de l'emplacement doit tenir compte du changement climatique et du retrait du pergélisol. Il faudrait éviter les emplacements où le substrat présente un contenu en eau élevé.

Réglementation et politiques

- Les normes de planification et les règlements pour la construction et le financement des habitations doivent être assouplis afin d'encourager l'adoption de systèmes de viabilisation, de structures financières et de modes d'occupation innovateurs.
- Il est recommandé de modifier les politiques pour encourager une construction écologiquement durable en ce qui concerne l'eau, l'électricité, l'aménagement du secteur chauffé, l'aménagement de l'emplacement et les bâtiments éloignés.

Partie deux : La technologie et l'information

Section trois : Les matériaux et la technologie

- À cause des grandes pressions que les humains exercent sur les ressources de la planète, il devient de plus en plus nécessaire de modifier la façon d'aborder la conception, la construction et le fonctionnement des habitations, en ajoutant le rendement environnemental comme nouvelle valeur. Cette section présente des choix technologiques qui sont économes de ressources et créent un lieu sain, confortable et non dangereux pour les occupants.

Section quatre : Ressources d'information

- Cette section énumère des ressources qui sont utiles en vue de la construction d'une maison saine durable dans le Nord.

Importance et conséquences

En dernière analyse, cette étude et ses lignes directrices visent à contribuer à la production dans le Nord d'habitations plus durables sur le plan écologique et mieux adaptées aux réalités locales et sociales pendant la construction, l'utilisation et à la fin de leur vie utile.



AU COEUR DE L'HABITATION

Canada

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le résumé a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

Centre canadien de documentation sur l'habitation
Société canadienne d'hypothèques et de logement
700, chemin Montréal, bureau CI-200
Ottawa (Ontario)
K1A 0P7

Titre du rapport: _____

Je préférerais que ce rapport soit disponible en français.

NOM _____

ADRESSE _____

rue

App.

ville

province

Code postal

No de téléphone () _____

Introduction

This study is a review of the principles and technical information that can influence the realization of healthy and more sustainable housing in the North. The objective of this study is to begin addressing and enhancing the ecological sustainability, social appropriateness, and total (real) economic aspects of northern housing. The approach is to develop the concept of the Healthy House in a northern context.

People who design and construct housing in the North need to become more conscious of their impact on the environment, social structures and energy use. High environmental and dollar costs of fossil fuel energy in the North demand reconsideration of conventional building design, materials and technical systems. The need for repairing and reinforcing the social fabric calls for appropriate environmental and cultural design to create healthy and locally supported, self-sufficient northern communities. This study reviews and examines influences, aspirations, limitations and potential solutions for increasing sustainability in northern housing.

The study is divided into two parts. Part One is Conditions and Concepts. It is made up of Section One, Land and People, and Section Two, Economics and Policy. It is an overview of the northern context, ecological sustainability, social appropriateness, and total (real) economic aspects of northern housing.

Part Two is Technology and Information Resources. It is made up of Section Three, Materials and Technology, and Section Four, Information Resources. Part Two includes a review of technical options and practical references for building healthy housing. It is intended to be comprehensive, instructive and fundamental. It will help a decision-maker increase his or her capacity for choice by referring to more detailed information and providing the means to investigate and apply appropriate Healthy House planning and building criteria in the North.

Conclusions and guidelines are presented by way of 'issues' and 'strategies' in summary form throughout the study.

The intent of this study is to encourage the inclusion of environmentally responsible Healthy House concepts, systems and materials in the design, construction, operation, and final disposal of housing. The study is intended for the use of decision-makers who can advance this goal. These may include private homebuilders and buyers; community planners, architects and engineers; regulators and administrators; and policy makers. Northern training institutions could also use the study to supply people with the

knowledge and skills to create northern healthy housing solutions. By reaching these audiences, this study and its guidelines should contribute to northern housing that is more ecologically sustainable and locally and socially appropriate during construction, in operation and at the end of service.

Towards a Northern Healthy House

This study is intended to provide an introductory resource to the principles and practicalities of ecological building in the North. The premise of the study is to analyze the five guidelines of the Healthy House in the context of current northern realities and the principles of environmental sustainability. The emphasis is to highlight northern issues and available northern, or best alternative, solutions. The result is a guide for conceptual design, development and promotion of a Northern Healthy House.

Healthy House Principles

The five principles of the Healthy House, as defined by the Canada Mortgage and Housing Corporation (CMHC), are as follows.¹

1. Occupant Health

A healthy house provides a safe space, good indoor air quality, no allergens, safe water, access to sun and views, safe lighting, control of sound and forms of radiation, and no toxins, pollution or harmful substances or radioactivity.

2. Energy Efficiency

A healthy house maximizes energy efficiency in space heating and ventilation, water heating, lighting, cooking, refrigeration and choice of appliances. Maximum energy efficiency can also be attained by considering the embodied energy in materials and products.

3. Resource Efficiency

The principle of resource efficiency affects choices of construction materials, products and technologies, construction methods, water, electricity and waste management. Life cycle considerations and recycling are important factors to consider when evaluating resource efficiency.

¹ Text adapted from CMHC – Healthy Housing, A Guide to a Sustainable Future

4. Environmental Responsibility

Environmental responsibility includes controlling pollutants, emissions, radiation, waste, grey water, sewage, landfill and earthwork. It is best achieved in combination with recycling and proper eco-management.

5. Affordability

A healthy house is affordable and financially viable, as supported by its sale appeal, design, life cycle costing and financial management.

Part One: Conditions and Concepts

1. Land and People

1.1. Introduction: The Environmental Imperative

We live on a human-dominated planet. Humans have modified one-third to one-half of the earth's land surface. We use more than half of all accessible surface fresh water. We have caused the extinction of one-quarter of Earth's bird species. We have increased the carbon dioxide concentration in Earth's atmosphere by 30% since 1800. We fix more atmospheric nitrogen than all natural terrestrial sources combined.² M. Wackernagel and W. Rees have noted that we would require the equivalent of 1.4 earths to be sustainable at the rate we are now consuming resources and creating wastes.³ A recent assessment from the Ecological Society of America entitled *The Sustainable Biosphere Initiative* states that, "environmental problems resulting from human activities have begun to threaten the sustainability of Earth's life support systems...Among the most critical challenges facing humanity are the conservation, restoration and wise management of the Earth's resources."⁴

Healthy ecosystems provide a long list of services. A partial reckoning includes the purification of air and water; mitigation of floods and droughts; detoxification and decomposition of wastes; generation and renewal of fertile soil; pollination of crops and natural vegetation; control of potential agricultural pests; dispersal of seeds and translocation of nutrients; maintenance of biodiversity; protection from the sun's harmful UV rays; and partial stabilization of climate (a particularly severe concern in the North where climate change is predicted to be greatest, and where increasing impacts are being experienced). Services also include moderation of temperature extremes and the force of winds and waves; support of diverse human cultures; and provision of beauty and intellectual stimulation that lift the human spirit.

The Ecological Society of America went on to conclude that "Based on available scientific evidence, we are certain that: Ecosystem services are essential to civilization...Human activities are already impairing the flow of ecosystem services on a large scale. If current trends continue, humanity will

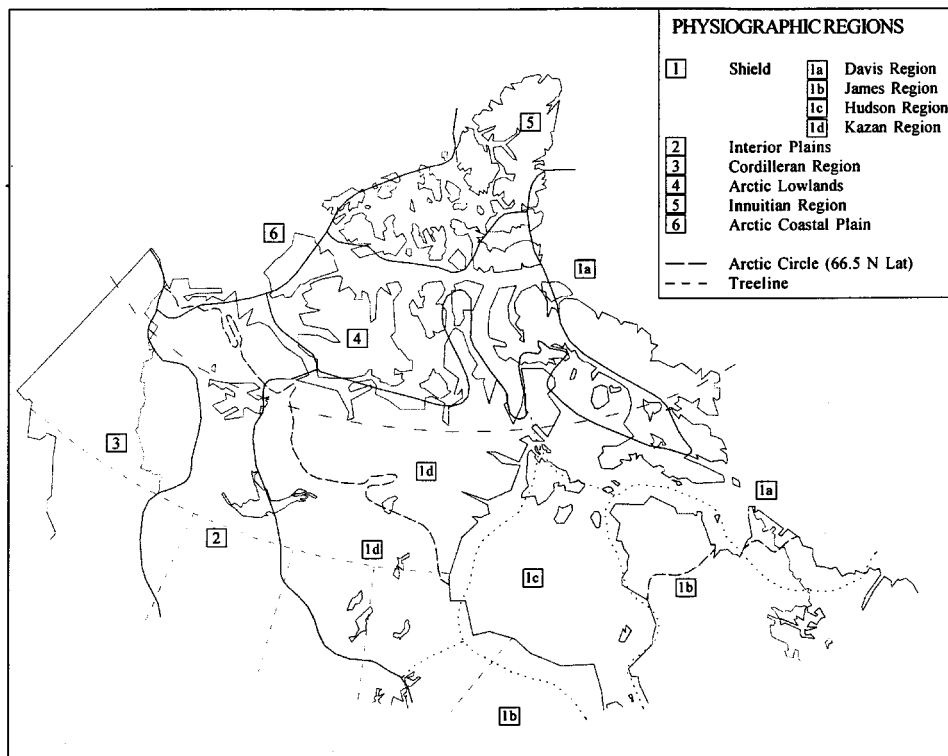
² P. M. Vitousek, H. A. Mooney, J. Lubchenko and J. M. Melillo, "Human Domination of Earth's Ecosystems" in *Science* 277(1997): 494-499.

³ M. Wackernagel and W. E. Rees, *Our Ecological Footprint* (Gabriola Island BC: New Society Publishers, 1995).

⁴ Jane Lubchenko, "Entering the Century of the Environment: A New Social Contract for Science" in *Science* 279 (1998): 491-497.

dramatically alter virtually all of Earth's remaining natural ecosystems within a few decades.”⁵

It is no longer questioned – humanity is living unsustainably. E. O. Wilson, a leading ecologist, has called this the Century of the Environment. We must take responsible action and reverse these trends. Many of our attitudes and accomplishments relevant to these issues begin at home, and housing is an important part of the learning environment within which the awareness of our integral part in Earth's ecology can develop.⁶



Map of Physiographic Regions

⁵ Jane Lubchenco, "Entering the Century of the Environment: A New Social Contract for Science" in *Science* 279 (1998): 491-497.

⁶ Donella Meadows, *A Building Can be a Teacher*. Available at <http://iisd.ca/pcdf/meadows/building.htm>

1.2. Physical Environment

The northern physical environment is simpler than most, although geographically large and diverse. It is a landmass with unique and powerful natural conditions, many of which directly influence housing design. The major issues in the physical environment are also closely related to and influenced by the people, planning and culture that inhabit it. The people who live here and their culture are a dynamic force that have an impact on and are influenced by this land.

1.2.1 Physiographic Regions

The Northwest Territories and Nunavut cover an area of over 3.4 million square kilometres (1.3 million square miles). About half of this area is the physiographic region of the Precambrian or Canadian Shield. (See the map of Physiographic Regions.) In the northwestern part of Canada's North, the southern edge of the Shield runs roughly parallel to and south of the treeline. The continental shield in the Kazan region is about 600m above sea level and typically varies in relief by less than 60m. This country is characterized by overlaying patches of muskeg, a number of large lakes and innumerable small ones, and about 10% surface outcrop. The shield near Hudson Bay (the Hudson region) includes the rocky islands in the bay and the Hudson Bay Lowlands southwest of the bay. In the East, a chain of mountains runs from Baffin Island to Ellesmere Island with heights to 3,000m (the Davis region).

The second most common area is the Interior Plains, which extend northward from the Great Western Plains, and lie south of the treeline. This is a complex geological zone of lakes, bogs, muskeg, and some plateaus and hills up to 750m in elevation. The Arctic Lowlands lie north of the Arctic Coast. This area consists of sparsely vegetated, mostly low rock (in some areas no more than 30m above sea level), and endures a long and severe winter climate. The Arctic Coastal Plain stretches along the northwestern coast of the Arctic Archipelago and includes the large Mackenzie Delta area.

Finally there are two mountainous regions. The Innuitian region lies north of the Arctic Lowlands within the Arctic islands, with elevations ranging from 120 to 600m and some mountains to 2,500m. The Cordilleran region is part of the great western mountain ranges and contains complex geology and elevations to 2,700m.

1.2.2 Ecozones

The continental North is divided largely into tundra and Boreal Forest ecozones. Tundra areas, which exist above the treeline and in alpine areas,

are subdivided further into Low-, Mid- and High-Arctic tundra, while Boreal Forest includes the Taiga (Taiga Shield and Taiga Plains), or land of little sticks – the zone of transition from tundra to forest along the treeline. The treeline runs in a northwest to southeast direction from the eastern edge of the Mackenzie Delta through the northern parts of Manitoba, Ontario and Quebec. Ecological subdivisions of the Arctic tundra ecozone are related to the height and densities that plants achieve given prevailing climate, permafrost and depth of the active layer, and soil types. Relative to the southern Boreal Forest, the Taiga has reduced biological diversity and hosts slowly growing trees in cold soils with reduced plant nutrients. Important and highly productive ecosystems within both the Arctic tundra and Boreal Forest zones are the aquatic and marine systems.

Because of the need to maintain the integrity of the permafrost, much of the North is ecologically sensitive to physical disturbances in the insulating vegetation and any environmental variations, including air temperature, solar radiation, water flow, precipitation and nutrients.

Large rivers and lakes, and marine areas are key elements of the northern physical environment. These water bodies are important for considerations of freshwater needs, transportation, food, wind and potential wave energy. They also provide heat masses for potential heat pumps, since their temperature is always greater than 0 °C even when the ambient temperature is less than -40 °C.

The natural ecology of the North supports a limited number of species in careful balance. The use of local wildlife as a food and economic resource is common in some areas. Caribou, moose, fish, birds and marine mammals are the most common wild animal foods. Barren-ground Caribou migrate in annual patterns from the Arctic coast to the edge of the Boreal forest. Related species include caribou of the Arctic Islands and Woodland Caribou of the Boreal forest. Fish for food and limited commercial use exist in most of the continental fresh water lakes. Over 200 species of birds breed in the North, many in the Taiga and Tundra ecozones. Ocean fish and marine mammals are an important resource in coastal regions. Small and large game provide food and a wild fur resource. Berries and mushrooms are some of the important food plants.

1.2.3 Climate

Arctic climate occurs where the average warmest monthly temperature does not exceed 10 degrees C. (See the map of Ecoclimatic Regions.) The southern limit of the Arctic climatic region approximately follows the western Arctic Coast and then southeast to Hudson Bay. This zone is also considered the Tundra ecoclimatic region, and includes all the northern archipelago to the North Pole. Below this line is the climatic region of the subarctic. This

includes the northern Mackenzie Valley, the area between Great Bear and Great Slave lakes, the northern half of Yukon and the most northern areas of Saskatchewan, Manitoba, Ontario, Quebec and Labrador.

Each climatic region is characterized by a different number of annual degree days (DD).⁷ Degree days are a useful measure for comparing the overall yearly impact of climate on different regions. (See the map of Annual Degree Days.) The Arctic climatic region defines an area north of approximately 9,000 to 10,000 Celsius degree days. This is comparable to approximately two to three times the potential heating load for the Ottawa climate. The subarctic can be roughly defined as the zone from about 10,000 Celsius DD to 7,000 Celsius DD (north of the southern limit of discontinuous permafrost). This is about 1.5 to 2.0 times the heating load for the Ottawa climate.

Photoperiod, or day length, in the North is an extremely variable factor. Depending on the time of year and location, it can range from 24 h/day to 0. In fact, the monthly average total hours of bright sunshine in the North exceeds the southern average for March through July (see Total Bright Sunshine Hours/Month). The mean daily temperature in July on the Arctic coast can average from 8 to 15 degrees Celsius. Therefore, parts of the Arctic climatic region can receive potentially useful solar gain for at least four months a year (April, May, June and July). In the subarctic regions this factor would be an influence for six to ten months. In evaluating potential solar gain, it is also important to consider the local conditions of cloud cover, especially in maritime regions.

Below the Arctic Circle, the altitude of the sun (angle above the horizon) at noon moves with the seasons through a fixed range of 47 degrees.⁸ In the North, the solar altitudes are low or non-existent. For example, at 62 degrees, (the latitude of Yellowknife, below the Arctic Circle) the angle varies from 4.5 degrees on the shortest day⁹ (approximately 5 hours) to 51.5 degrees on the longest,¹⁰ (approximately 20 hours). On the arctic coast, at 68 degrees latitude (above the Arctic Circle) the sun's altitude moves from 0 degrees (no day) to 45.5 degrees (24-hour day).

This low sun angle in the North has two interesting characteristics that are relevant to building design. First, a vertical wall becomes very effective as an irradiation surface. At 64 degrees latitude (mid-Kazan physiographic region) from mid-March through mid-September (six months), the daily solar

⁷ The number of Annual Degree Days (Celsius) is the cumulative addition of all the degrees for each day with a mean temperature below +18 degrees Celsius. This number therefore offers a statistical basis for the approximate comparison of heating requirements.

⁸ The Arctic circle is the latitude where the sun descends to 0 degrees at the winter solstice (shortest day) and will therefore rise to 47 degrees on the summer solstice.

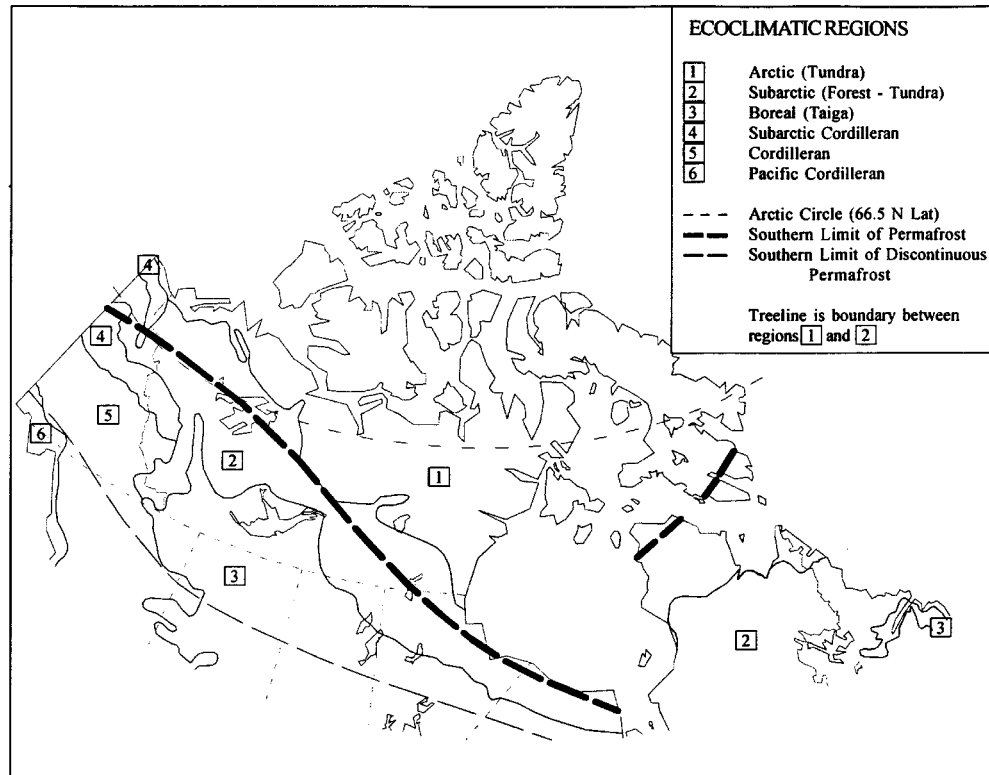
⁹ winter solstice

¹⁰ summer solstice

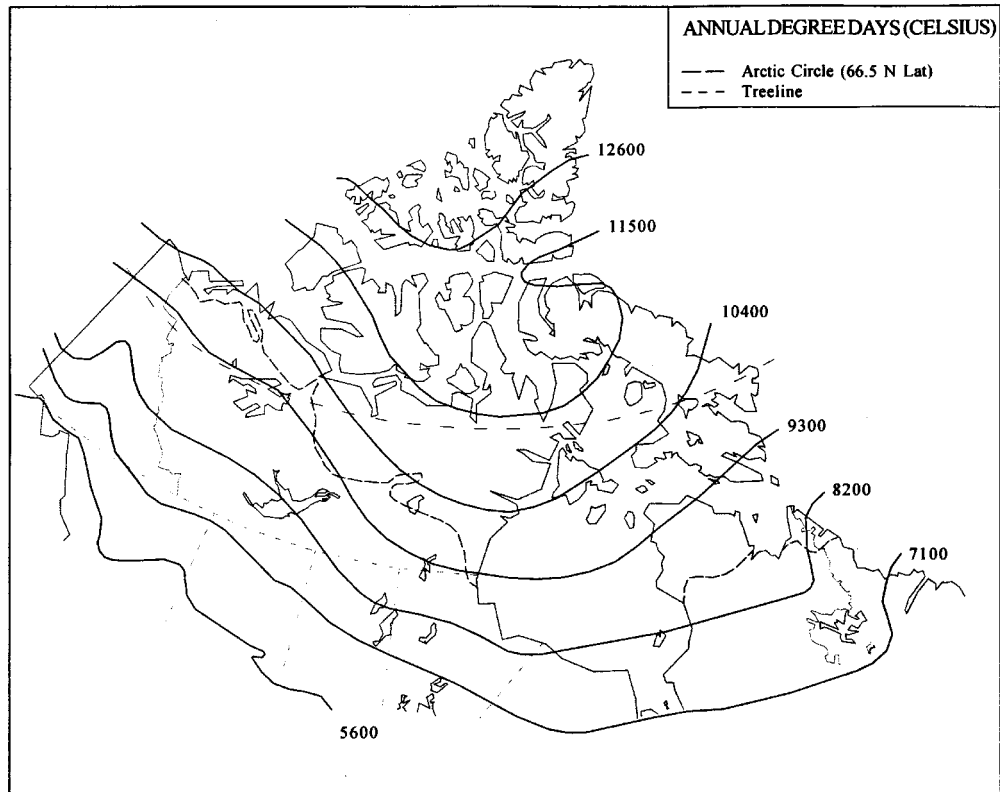
irradiation on a vertical wall equals, or exceeds that of a wall at 48 degrees (e.g., the latitude of southern British Columbia).¹¹ Second, because of the broad arc of the sun in northern latitudes, special conditions will occur on east- and west-facing walls. At 65 degrees latitude (mid-Kazan physiographic region) on the summer solstice, the sun rises at 20 degrees east of North and swings through 340 degrees before setting at 20 degrees west of North. By about 7 a.m., the sun is due east and higher than 20 degrees altitude (above the horizon). This characteristically northern phenomenon can offer solar gain potential on east walls in spring but also may result in overheating from windows on west walls in summer. This raises unique challenges for using solar gain in spring and summer without high heat loss in winter.

Wind is always an important factor in design. In areas above the treeline, consideration of the wind is critical. Communities in the Tundra climatic region generally experience winds in excess of an average of 20kph throughout the year. (See Mean Wind Speed.) Wind increases heating loads and carries and deposits snow. It is a drying and ventilating element in summer and winter. It also represents a potential, local source of renewable energy if used to create power.

¹¹ from ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) *Handbook of Fundamentals*, chapter 59.

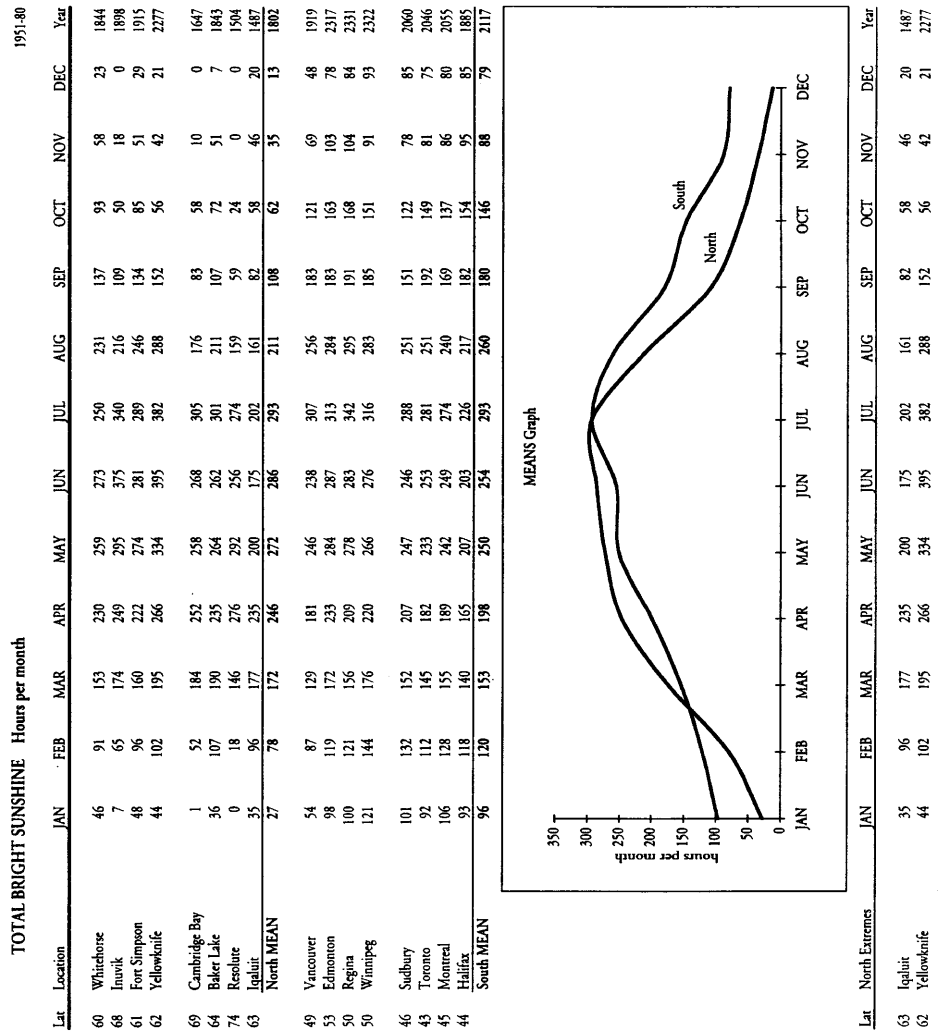


Map of Ecoclimatic Regions



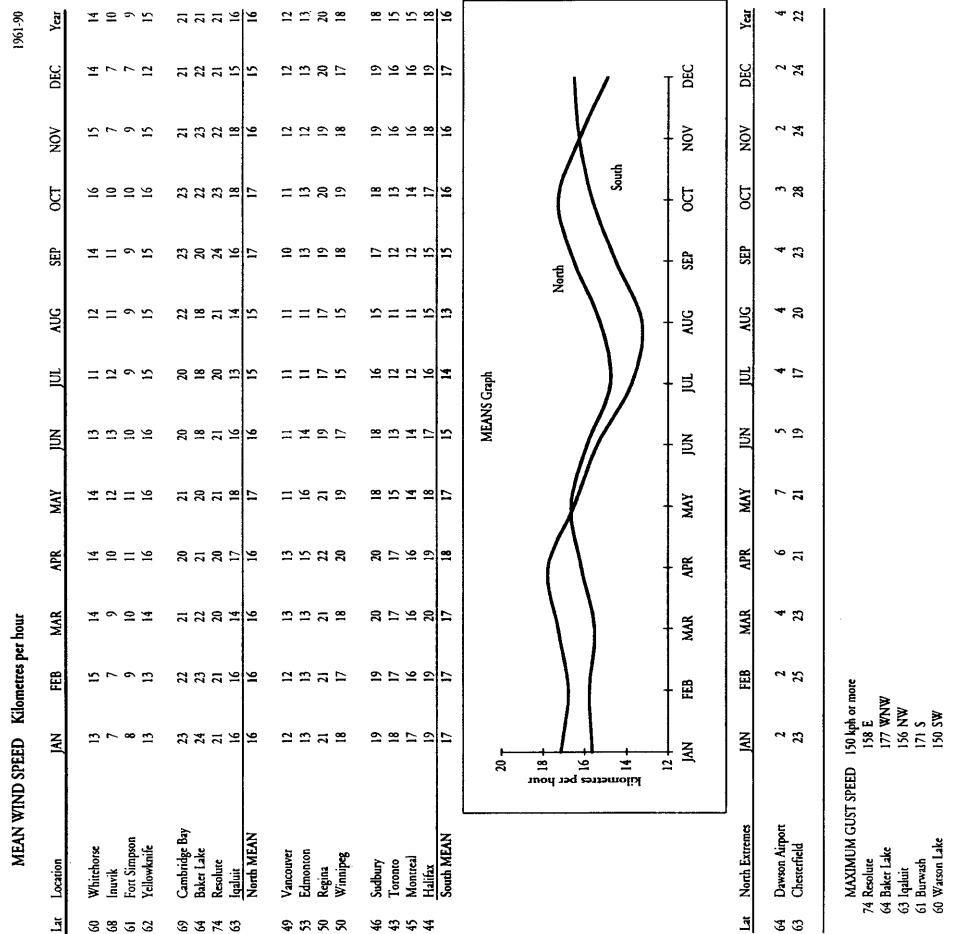
Annual Degree Days (Celsius)

Total Bright Sunshine



from Strub, Harold. Bare Poles: Building design for high latitudes.
Ottawa: Carleton University Press, 1996. p. 168.

Mean Wind Speed



from Strub, Harold. Bare Poles: Building design for high latitudes.
Ottawa: Carleton University Press, 1996. p. 173.

1.3. Planning Environment

1.3.1 Introduction: Northern Aspects

Housing design is characteristic of a culture. It responds to and illustrates the needs of a specific culture. Current housing design has evolved over many years to suit the needs of current modern culture. Compared to the rest of Canada, modern housing has arrived only recently in the North. Houses in the North are standing examples of the history of housing innovations. With good reasons, some of the housing designs and technology represent real advances. Sets of ideas and innovations – such as R-2000 technology, the healthy house, the smart house, the sustainable house, or new construction methods such as panelized construction or truss walls – are meaningful in the North only if they can be applied to local conditions. A northern healthy house would need to suit the needs of the people in the North. It is not coincidental that North American houses have living rooms that seem to be designed around the TV, or that these same houses have kitchens that are not designed to butcher game. Housing needs are culturally specific.

The North, like Canada and the rest of the world, experiences many global forces that influence housing design. However, in the end, it is not the global or national, common needs that will determine the success of innovations. It is the local differences that need to be understood and planned for. The planning process needs to respond to these differences. Universal concepts of the Healthy House need to be translated through a participatory and cooperative planning process to address the unique characteristics of local conditions.

When we consider our housing needs we quickly come up against a dilemma, as follows: Environmentally and ultimately, for our long-term viability as humans, we realize that we need to live within the limits of our environment. Thus we *must* incorporate higher efficiency, renewable energy, local products and other sustainable measures in our housing. On the other hand, from a conventional economic perspective, we feel we can *not afford* the high, up-front capital costs to create efficient buildings. Using renewable energy and recycled and reusable materials that yield low maintenance and servicing costs necessitates higher construction and material costs, at least until we sway practices to commonly adopt these protocols. Ultimately, we hope that builders will apply the philosophy and guidelines described here, and help swing affordability towards what we know are essential practices for healthy communities.

Social and environmental (and thus economic) costs will continue to escalate until we have developed appropriate mechanisms to support the responsible housing practices that are required to achieve sustainable living. Fortunately, civil society is increasingly responding to the need to restructure

our ways of living and doing business so that environmental and social as well as economic costs are clear, and support is becoming available to make the transition towards living in an ecologically sustainable way. Norman Myers and others have revealed that simply removing some perverse subsidies, defined as those that are bad for both the environment and the economy, would go a long way towards supporting more appropriate and sustainable activities.¹² Given this support, we can regain a secure and healthy environment, more robust local and regional economies, and conditions of social justice that promote the opportunity for all people to reach their human potential. Such an evolution is happening, and it is requiring the participation of all segments of our communities and governments – service providers, policy-makers, regulators, construction companies, home owners, town planners and others.

In the North, we have our own unique set of conditions relevant to housing that need to be specifically recognized. For example, we have long periods of extreme cold, several months when the sun is above the horizon for only a few brief hours or less each day, and in contrast, other months when the sun lingers overhead for many long hours each day. Our region is one of generally low biological productivity due to permafrost and a brief growing season. We have a low, dispersed human population with low local abundance of, and/or often low accessibility to, building materials and skilled labour. Almost all of our communities are associated with large bodies of water – rivers, lakes, and oceans – that offer opportunities for efficient access to clean water, wind energy and heat sinks. Northerners' lives are often closely associated with the land as their means of sustenance and economic well-being. Because of extremes in our environments, traditional services are costly in energy, resources and dollars. These conditions represent both challenges and opportunities for today's northern healthy house builders, and are the subjects of further exploration below.

The most effective way to work towards ecologically compatible homes is to build housing that is locally appropriate in scale, design, use of building and operational materials, and disposal. This overriding approach will govern much of the decision-making we will encounter on our journey towards northern, ecologically sustainable building.

Housing is one of the fundamental characteristics of one's culture. Styles of housing vary widely according to local environments, available resources and regulations. In North America, however, we have adopted a common style of housing that is not universally well adapted to our varied environments and lifestyles. Further, this style of housing and the servicing it

¹² See N. Myers and J. Kent, *Perverse Subsidies: Tax Dollars Undercutting our Economies and Environments Alike* (Winnipeg MB: International Institute for Sustainable Development, 1999).

requires are notorious for their energy inefficiency and high rate of consumption and waste production. Consequently, this model of housing serves us poorly. Partly in response to this, the CMHC has developed the concept of the Healthy House. In this study we explore and expand the principles and application of this concept to northern Canada. For this purpose, we understand healthy house to mean healthy for people, for the environment and for our economy.¹³

1.3.2 Expectations

It is a fair generalization to say that the population of the North reflects the behaviour and expectations common to the rest of Canada. Like every corner of the world, the North is part of an interacting global culture. The people of the North have the modern sense that the future should be better, easier or cheaper than the past. It is the common understanding that this result is possible if the right combination of economics and technology is applied correctly to any problem, whether personal or at the scale of the community or world. However, realizing this expectation may not be easy when all circumstances are examined. For example, maintaining goals of continuing growth is now seen as impossible. Providing for reasonable levels of service and quality of life is more realistic – this is the sufficiency part of the equation. Although it seems very necessary, it is difficult to provide strategies that can address this need for change in expectations. A starting point would be to raise awareness of the alternatives and the externalized costs to others of gross overuse of resources. Until these alternatives become more widely accepted, and full costs understood, expectations will continue to be greater than what can be delivered.

1.3.3 Characteristics of the Population

There is a danger in oversimplifying the characteristics of any population. While demographics and other factors are useful tools for planning, it is important to avoid sweeping a large group of people with the same brush. The unique cultural conditions in the North vary considerably, even amongst a seemingly similar population. Instead, demographics can suggest general trends and provide a broad overview of the population as a starting point for understanding more specialized differences.

In the approximately 4 million square kilometres of Yukon, the Northwest Territories (NWT) and Nunavut (over one third the area of Canada) live about 97,000 people (about 70% of the population of Prince Edward Island). About 35% of the northern population is age 19 or under. The urban population (in

¹³ See Section 1.3.4, Housing and Change, for a discussion of the complex interplay between these three factors.

towns over 3,000) is about 50% of the total, or 51,000. The cities of Yellowknife (17,900) and Whitehorse (22,900) account for about 42% of the total population of all three territories.¹⁴

About 50% of the combined population of the three territories are non-native and predominately speak English. This figure differs widely from 21% in Yukon, to 51% in the NWT, to less than 20% in Nunavut, where 80% are Inuit.¹⁵ The NWT also includes the Dene, who traditionally speak Slavey, (northern and southern dialects), Dogrib, Chipewyan, Gwich'in, and Cree, as well as the Metis.

This sparse population is characteristic of the northern areas of Canada. However, it is also evident that these characteristics are complex. Although the population is small, it is diversified and specialized. A breakdown is usually made between people of western cultural traditions and those of Aboriginal traditions. Demographics show a strong tendency of urban settlement for the former and rural settlement for the latter. The urban populations are more integrated in the wage economy, a characteristic which continues the pattern of administration and utilization by the transplanted culture. This cultural, historic and persistent difference is often commented on and analyzed. It is a clear fact that the interjected culture of the western (Judeo-Christian) tradition expresses some fundamental differences from those of the Aboriginal peoples. In the 200 years since first contact, these differences have been well documented and continue to have an impact on many aspects of northern life. Changes in housing are a more recent example of these differences. The impact of modern housing and services and community living spans only about 50 years. The introduction of modern housing in the North is a living memory held by many people who are alive today. The cultural differences that are expressed through housing are significant, since they reinforce the fundamental aspects of how we live.

Although the historical cultural differences are undeniable, they are also a broad oversimplification. These two characteristic groups are not homogeneous. Complex interplay and division exist between and amongst various interests. There are several Aboriginal languages and differences in traditional ways of living. (In the Northwest Territories, there are 11 official languages.) The institutions of schools, government, politics and business have affected cultural attitudes. Views of the meaning and importance of the biosphere for scientists and administrators are changing. There is an increased importance placed on the necessity for sustainable living. The influences of local control, local agreements and self-government are more common. Business forces are more powerful and demographically complex.

¹⁴ *NWT Statistics Quarterly* vol.22 #4 Dec. 2000, *Census of Canada* 1996, www.nunavut.com, www.gov.yk.ca, www.gov.nt.ca

¹⁵ *Ibid.*

It is therefore increasingly impractical to categorize housing by urban, rural or cultural group.

1.3.4 Housing and Change

The introduction of various types of modern housing and subdivision designs to northern Aboriginal cultures over the past 50 years has both represented and reinforced changes in society over the same period. The effect of contact between western and Aboriginal cultures is still very recent for some people. In only a few generations, many changes have affected the North. First, an abrupt and fundamental change occurred from a seasonally mobile to a sedentary existence. The creation of communities provided the necessities of life as emergency relief, but also facilitated full reliance on alien-dominated institutions such as residential schools, health services, police, government and commercial interests. This is well documented. Over the last 40 or 50 years, northern housing evolved and became more modern. Except for minor differences, new houses in the North are designed and sited like houses anywhere in North America. Modern house design has supplanted older values and encouraged new ones. Modern plumbing has created healthier conditions, but also a house-centred and more interior lifestyle. The modern house needed a new kind of management, including specialized service and repair. It could not be seasonally abandoned, even for short periods of time. Rental tenure was necessary due to high capital costs, but this form of tenure then eroded self-reliance. Efficient lot divisions have reinforced concepts of ownership and administrative control. As the lots became smaller and the houses became bigger, less space was available for storage of gear and exterior activities such as keeping dogs, smoking fish and curing hides. Kinship groups broke down, since a generational growth pattern is antithetical to subdivision type development, which is generated around efficient servicing. As everywhere, the influence of commercial culture is delivered by the dominant force of mainstream media, TV, and the interior lifestyle of the living room. To some, these changes may seem very normal and even necessary. Others from both the Aboriginal and non-Aboriginal cultures argue for the return to their own past values. The important point is to acknowledge that many forces of change in Aboriginal cultures are related to and promoted by the design of the modern house and subdivision, and occurred within the last 50 years. Aboriginal cultures can recall another type of existence from recent memory that was stable, complex, whole and self-sufficient.

1.3.5 Localization

The cost of today's extremely high rate of consumption is largely levied externally, against people in developing countries and to future generations – our children. To achieve global equity, defined as the equality of resources and opportunities amongst all, we must decrease our consumption, ultimately by 90% of today's average level of material and energy per capita use in westernized society. H. Norberg-Hodge, V. Shiva, W. Sachs and D. Korten are among the select cadre of writers, thinkers and activists who have made detailed studies of links between environment, economics and social justice. They are unanimous in their conclusions that we cannot learn to live sustainably unless we do it through means that contribute to more socially just relationships around the globe. Norberg-Hodge, through her discerning long-term study of a high-altitude people in the Indian province of Ladakh, has clarified the process through which today's globalized market economy leads quickly to the decimation of a previously healthy and self-sustaining society and to the loss of its associated characteristics of compatibility with the environment, and social well-being.¹⁶ A key theme recognized in such studies is housing. The studies detail how, under the original conditions of a localized economy, housing is ingeniously adapted to local conditions, it is resource-efficient, and it complements local lifestyles.¹⁷

A further corollary of these conclusions is that localization – the return to self-sufficiency based first and largely upon local and regional resources – leads back to sustainability. Thinking holistically, localization represents the road towards a secure natural environment, which is a prerequisite for healthy local economies and healthy communities. This finding has major implications for housing, particularly in the North, where building often occurs in remote communities having difficult access and an existing, high dependency on imported materials and fuel. These implications are systemic and include ramifications on how we build, as well as how locally-based construction contributes to local economies and community life.

1.3.6 Participatory Planning

A model of participatory planning is fundamental to accommodate the widely varying conditions of people and infrastructure in the North. The many differences are best addressed in consultation with the people whom planning will affect most.

¹⁶ H. Norberg-Hodge, *Ancient Futures: Learning from Ladakh* (San Francisco CA: Sierra Club Books, 1991).

¹⁷ See Section 1.3.6, Participatory Planning, for a discussion on socially and culturally-responsive planning processes.

As noted before, a large percentage of the northern population lives in a few small cities. These cities or towns usually have a tax base and a structured development plan. The plans have generally been developed from a southern model based on the conventionally efficient delivery of public services. The majority of the Aboriginal population lives in smaller communities. In the past twenty years, the ideas of southern planning have been felt in most of these communities. These planning principles come from the tradition of western urban design and are concerned with fire separations, property divisions for ownership, and sanitary and health standards. In addition, as road or air infrastructure entered into a small community, a plan was soon devised to rationalize service access.

Some of these principles are now seen by some western planners as flawed. In many communities the earlier 'informal' planning stands out as diverse and organic, while the later 'access' planning is seen as uniform and mechanical. This is understandable, since much of recent development is designed to limit any uniqueness that could become a technical or administrative problem. The earlier (informal) planned community had a high level of local control and was a slow process. Houses often developed in kinship groups over many years as families grew. When the authorized government determined it necessary to improve roads or sanitation services, the local planners had less local control and lots needed to be developed in 'batches'. This resulted in new sections of communities that visually symbolized the intervention of a non-local influence. This alienation with the form and process of planning of housing has often been cited as one reason for social alienation and lack of care. In more recent years a higher and more concerted effort for community and user input has resulted in more responsive development. This process should be continued and enhanced in the future. The devolution of control for development can result in an improved sense of community responsibility.

New technical developments also make principles of user-controlled development more feasible. Technologies such as mini-sewage treatment systems, grey water recycling systems and solar power hybrid systems allow a person to generate power or process water in his or her own house or neighbourhood. Newer technologies allow for service flexibility and user control. When safety issues and servicing can be addressed at the level of the individual house, there is far greater flexibility in siting the house. For example, with efficient generators and wind or solar power, outpost camps can become viable options.

Nevertheless, technically advanced northern houses can be expensive and will probably increase in capital cost if they become more energy efficient. To catch on in the North, newer energy-efficient technologies must become financially feasible and easily operable. While subsidies are desirable incentives towards encouraging sustainable building principles, they

raise other problems. A large subsidy to homebuilders or owners undermines concepts of self-sufficiency and often must limit user control. At this critical point in political awareness, it is important not to overwhelm local users with new technical and financial dependencies – more practical and desirable would be the removal of subsidies for competing, unsustainable systems. Many issues will continue to impact the process of housing design, including issues of technical systems, their operation, the natural ecology, the community's needs, financing and tenure. These issues remain to be resolved. Many of these issues are discussed in more detail in Section 2.5: Regulations and Policy.

In recent years a more participatory and inclusive design process has resulted in some improvements in northern house design. Programs that encourage local involvement and control are usually received better by communities and are more successful in social terms. These efforts are sometimes looking for long-term betterment. The evolution of political control in Nunavut and self-government in other areas may alter the administration of planning. It is impossible and dangerous to generate the needs for this small population based on generalized characteristics and predictions. The planning process cannot be reduced to creating large categories such as Native, remote, advanced or healthy housing.

As much as possible, the planning process should address individual situations. This process should include a review and understanding of what activities are happening now and what activities would be preferred in the future. The planner's role is to consider the needs, motivations, expectations and results of present and proposed activities. Asking appropriate questions can help to direct this role: Who is participating, who is not and who is in control of the process? Who stands to gain or be passed by? What are the important beliefs carrying significant meaning and what are the habits that are encouraged by perverse circumstances? In such an analysis there should also be contextual questions about how the traditional (past) activities related to and affected the user, the community and the natural ecosystems, and how the new activities that are planned will affect the human and natural ecology well into the future. A number of additional questions could be asked: What are the long-term goals of this community? Can this plan help? Can this plan make even a small step towards long-term goals? And what are all the costs to the user, the community and the ecosystems? By addressing individual situations with these questions and similar ones, participatory planning can start to respond to the diverse and specific needs of the northern population.

Issue:

Culture, diversity and self-sufficiency

The demographics of the North are varied and specific. Within the small population there is a wide range of needs, expectations and meanings that are related to region, culture, infrastructure and environmental awareness. It is impossible to generalize planning for healthier, energy efficient housing in a meaningful way. Housing solutions need to be specific to the user and his or her capabilities.

In addition, technical advancements run the risk of decreasing a user's self-sufficiency, if they place dependency on financial subsidies or technical assistance for their operation.

Strategy:

Use flexible and participatory planning principles to accommodate specific needs.

1. Devolve control and broaden the context of the planning process to include relevant global and community environmental issues.
2. Use a participatory planning process and avoid universal solutions. Planning decisions work best when derived from local needs and resources.
3. Consider the context of planning and technology.
4. Promote plans that develop local human resources.
5. Evaluate newer technologies that allow for service flexibility and user control.
6. Avoid projects that are out of scale to local control or resources.

1.3.7 Neighbourhood

The factors that will be used to plan a neighbourhood need to be specifically developed and controlled by those who will live with, and be affected by, the planning. However, as obvious as this may seem, this condition is often not the case. Authorities that are mandated to act for the collective good or for the benefit of a specific interest often control the planning process.

Sometimes this control comes from an embedded economic right. For example, a developer has the right to choose a market and make money on the housing. When housing is considered solely as a product, factors affecting its function as a basic social service are often overlooked. On the other hand, the externally managed process has several advantages. Policy can be implemented on a regional basis. Safety and health concerns can be addressed quickly and efficiently. Documentation and cost recording can be uniform or centralized and used for future reference. However, this

centralized management structure can overlook distinct user needs at the local level. Local control will generally lead to more user-oriented planning. This usually evolves into socially healthy, successful results. Important factors that influence design are often unique to each neighbourhood.

It is wise to avoid attempts to blindly apply solutions that work in one community to another. Northern communities are not homogeneous or uniform. For example, some towns are urbanized and well serviced. Other, small villages are accessed by winter or all-weather roads. There are Arctic centers with jet access and other small, high-Arctic communities that are served by smaller planes.

All of the above characteristics are best addressed as part of a user-driven or participatory planning process. Questions that raise issues of cultural distinctions, which were outlined previously in Participatory Planning, should also complement any analysis of physical and sociophysical characteristics.

1.3.8 Tenure

Ownership is not as common in the North as in southern parts of Canada. In parts of the North (i.e., Northwest Territories), there are about twice the number of renters to homeowners.¹⁸ This is about four times the national rate. This pattern may have several causes. Many jobs are affected by the transient nature of the non-renewable resource extraction economy. There is also a higher risk for lenders, and the status of some land does not allow for conventional ownership tenure. There is a low rate of wage economy employment in some communities. The high cost of the detached house in the North and the high cost of operation (i.e., energy and utility costs) also inhibit ownership.

At least two conditions will continue to push up this cost. As subsidies are removed, the cost of conventional operation escalates and is transferred to the individual. Second, new materials and technologies, higher energy efficiency standards and increased built space due to family growth and/or raised expectations can raise the capital, up-front cost. The future role of detached-house ownership in the North is a complex issue beyond the scope of this report. Here, it will suffice to say that this housing form and tenure cannot automatically be seen as the ideal goal for all areas in the North. Attached houses result in lower heat losses for the same floor area. For example, a two-storey interior row house uses about 30% less fuel than a one-storey detached house of the same floor area.

¹⁸ CMHC. *The Long Term Housing Outlook, 1991-2016* and *Canadian Housing Statistics*, 1999.

Issue:

Ownership tenure may not be possible or desirable in all circumstances.

Strategy:

Consider alternative types of tenure and building forms.

Consider various types of tenure that already apply innovative concepts, materials or systems:

co-operatives; co-housing; forms of shared ownership, forms of corporate (for profit, not-for-profit), serviced and non-serviced land leasing; sweat equity for construction.

Consider various attached building forms.

1.3 Summary List

Following is a summary of major issues and characteristics of the physical environment and socioeconomic infrastructure that influence the design of communities and housing in the North. These are important considerations for examining planning options for ecologically sustainable design and construction of a northern healthy house. They provide a useful preliminary checklist of factors.

1.3.9 Physiographic, Climatic and Environmental Factors

physiographic zone (shield, plains or mountains)

climatic region: arctic or subarctic

permafrost: continuous or discontinuous

ecozone: Arctic Tundra or Boreal Forest/Taiga

below treeline: Taiga Shield or Taiga Plains

above treeline: Low-, Mid- or High-Arctic Tundra

Considerations related to these factors:

snow accumulations

solar and/or wind energy and effects on design

low solar influence (4 months)

medium solar influence (6 to 10 months)

availability of local lumber

local economics and the potential for community members to provide their own fuel or building materials

wild food resources
migratory species
foundation types / building materials

1.3.10 Water Body (coast, river, lake): Marine, Riverine, Lacustrine Locations

potential for wind power and heat pumps
water supply
coastal and lake species

1.3.11 Latitude

availability and real cost benefit of low embodied energy building materials (full cost accounting)
The further south, the more likely it is of benefit to access such materials, while communities further north should seek local material replacements to the extent possible.
potential solar and wind power

1.3.12 Modes of Access

possible modes of access (barge, road, rail, air) and seasonality (dates of access)
all-weather road(s)
winter road(s)
jet airport (in combination with other modes or as the only access)
small airports (in combination or as the only access)
navigable water

Considerations related to these factors:

real costs (full cost accounting) and benefits of transportation, reusing and recycling
need to plan efficient delivery of materials for construction and operation, and have flexible building schedule

1.3.13 Sociophysical Infrastructure

The following elements are factors of infrastructure and human ecology.

high schools
K to 8 schools
administrative centre(s)
business and service centre(s)

- traditional community cultural centre(s)
- hospital(s)
- health centre(s)
- availability of training for trades
- type of settlement:
 - urban centre
 - town
 - community / small settlement
 - camp
- site attributes
 - services:
 - fossil fuels
 - wood fuel
 - sewage
 - potable water
 - electrical power
 - communication (telephone, computer, TV)
 - wired, wireless, cable, antenna

Considerations related to these factors:

- primary lifestyle of community members
- local economics
- land ownership, tenure
 - Economics of building depends on this factor.
 - Total costs are lower if land is owned already, allowing more capital to go into efficient building with low operational costs.
- local and regional population size
 - economics of different options
 - likelihood that materials are available locally or regionally
 - local/regional need to develop these
- design options and process
- views
- relationships to other buildings

2. Economics: Ecological Sustainability, Socioeconomics and Full Cost Accounting

2.1. Introduction: Ecologically Sustainable Building

Shifting our housing practices in the direction of ecological sustainability means acknowledging that the biosphere is finite, and that achieving greater social justice must be met within the bounds of this limitation. Ecologically sustainable building requires that we recognize material flows, including energy, as both input and output, or waste stream. It requires reduction of flows through improvements in efficiency, and exploring and implementing the concept of sufficiency – i.e., reducing our material and spatial expectations. Achieving increased efficiency and recognizing that less is sufficient leads to a reduction in our ecological footprint.

Several useful concepts are outlined here to aid in decision-making when designing, building, operating and disposing of an ecologically sustainable home. These closely related concepts include *life cycle analysis*, *embodied energy* and *full cost accounting*. The latter concept includes 'real' economics, which ultimately deals with the ecologically meaningful exchange of energy rather than money.

2.2. Economic Analysis

2.2.1 Life Cycle Analysis

The total environmental footprint of a building, material or system is determined in an environmental *life cycle analysis* (LCA). Often referred to as a cradle to grave assessment, LCA looks at the environmental costs of resource extraction and manufacturing, on-site construction, operation and maintenance, and final disposition, including demolition or deconstruction followed by recycling, reuse or disposal of each material and system used in a building. Most current building practice tends to compare only capital costs when choosing a site, materials and building systems. Life cycle analysis is a good first step towards determining a building's environmental impact over its lifetime. LCA is a detailed and challenging undertaking to contemplate as a home builder, but fortunately material and system analyses are becoming increasingly available. Some current sources are referenced in the resource section of this report (Section 4). For an excellent example of LCA, see the *Environmental Building News* newsletter 9 (11), November 2000, which reviews Gypsum interior finish systems.

2.2.2 Embodied Energy

Embodied energy is the total energy consumed in all the processes that go into the extraction, manufacture, operation and disposal of a product or building. Rather than tallying specific environmental effects, as does LCA, embodied energy looks specifically through the lens of energy – a fairly reliable index of environmental effects. Energy is the common currency of all consumption, so it is a good common denominator with which to compare costs of materials, products or buildings. Studies of embodied energy can pinpoint where the largest environmental costs reside, providing focus in our efforts to minimize these costs and maximize benefits of recycling. Carbon dioxide emissions, the principal cause of climate change, are highly correlated with the energy consumed in manufacturing building materials. The energy embodied in existing building stock in Australia, for example, is equivalent to ten years of the total energy consumed by the entire nation.

Choices of materials and design principles have a significant, but previously unrecognized, impact on energy required to construct a building. There are many factors to consider when making these choices. The embodied energy per unit mass of materials used in building varies enormously from about two gigajoules per tonne for concrete to hundreds of gigajoules per tonne for aluminum. To choose preferred materials on the basis of embodied energy, one should consider the differing lifetimes of materials, differing quantities required to perform the same task, different design requirements, and the materials consumed over the life of the building during maintenance, repair and replacement.¹⁹

The reuse of building materials commonly saves about 95% of embodied energy, which would otherwise be wasted. Some materials, such as bricks and tiles, suffer damage losses up to 30% in reuse. The savings from recycling materials for reprocessing varies considerably – savings can be up to 95% for aluminum but only 20% for glass. Some reprocessing may use more energy, particularly if long transport distances are involved.

Embodied energy of buildings is often 10 to 30 times the *annual* operating energy consumed. This ratio will grow larger as buildings become increasingly more efficient, although the embodied energy of the building may also increase to achieve the greater efficiency expected. Most embodied energy of a building resides in concrete and steel, even though these materials have the lowest embodied energy intensities (values) of materials used, because so much of each is used.

¹⁹ See section 3, Materials and Technology, for an analysis of embodied energy for some specific materials.

2.2.3 Full Cost Accounting

Full cost accounting (FCA), including 'real' economics, assesses environmental, energy and social costs relative to net benefits, recognizing the finiteness of our biosphere and the ecosystem functions necessary for a complete and healthy biosphere to perform in order to enable indefinite human occupation of Earth. As the British company Low Energy Designs puts it: *The economy is a fully-owned subsidiary of the ecology*. For example, coercing a developing country to grow for export a cash crop such as cotton in an environment where there are few, if any, components of cotton's indigenous habitat, results in a number of ecological and socioeconomic effects: the displacement of locally adapted crops (often subsistence food); the need for pesticides to allow cotton to grow because it does not have natural resistance to local disease organisms; the subsequent loss of ability by the growers to provide for all of their needs locally; and the subsequent dependence of these people on the extreme variations and fickle market conditions of the global economy. Ultimately, people's health suffers from lack of proper nutrition and exposure to pesticides through direct means and through their food and water. Finally a loss of self-sufficiency and self-respect ensues, leading to major social upheaval and cultural loss. In summary, FCA reveals that in this situation there are no real benefits of growing cotton for export, though this is seldom identified through conventional economics which undervalue subsistence, social health and the local economy.

Similarly, to use a northern example, the full costs of freighting materials are high. In addition to the greenhouse gases and other pollutants emitted by the transport vehicles themselves, construction and maintenance of infrastructure such as roads, parking lots and airports contribute to further emissions and high costs. Increased access to imported materials erodes cultural integrity and the self-sufficiency of the local population.

Failure to account for these real, but seemingly hidden, costs leads to a continuing over-expenditure of natural and social capital. Suddenly, when completely overtaxed, the system breaks down and costs become obvious. Unfortunately, in a depleted environment, these costs are often irreversible in the short term.

2.2.4 Affordability

To make sustainable building practices more affordable, financial regulations need to account for not just the capital cost of the house. They need to account for the savings due to reduced operating and maintenance costs over a healthy house's lifetime. Changes to financial regulations on the use of capital will need to be made at the national and international levels.

Unfortunately, local communities have a minimal influence on these regulations.

Some changes to the current system of financial regulations would be necessary. The current regulations are coupled with a conservative administrative attitude to minimize exposure to risk and maximize return, and are built into the conventional development process. Banks approve mortgage values based on equity and income. Operational costs and total life cycle accounting are not commonly considered. The lender is generally not interested in costs or benefits beyond the time required for discharging the mortgage, since they have no (readily apparent) impact on the value or risk of the loan. Banks or lending agencies are reluctant to finance novel concepts, materials or systems. They see these as an increase in the level of risk, regardless of the amount of data or evidence that can be produced. To a bank, a house is only an investment, and innovative housing is an unknown, risky market in which to try to regain its loan in the event of default.

Houses with higher insulation values, high-efficiency equipment, or materials and methods that reduce waste, usually have higher capital costs than conventional housing. In the North these costs raise the existing high development costs even more. Also in the North, the high cost of housing is not always balanced by high equity or income. The boom and bust economic model, based on resource extraction industries, affects job security and perceived risk for the homebuyer. Even if pay-back times are shown to be shorter in the North, the increase in capital required to build or purchase a house is a tangible disincentive to improvements in housing. As long as such disincentives exist, it will be difficult to improve the average house in the North to R-2000 or higher standards.

One way this disincentive can be addressed is by an increase to the amount of maximum approved mortgage for a given level of equity and income. In the calculation for the mortgage, lenders need to consider the maximum costs of energy and maintenance over the life cycle of the house. The monthly savings identified in this calculation can be put towards an increase in the monthly mortgage payment. These higher payments would then enable the homeowner to take out an increased mortgage to cover the higher capital costs of the house.

The advantages may not be self-evident. Homebuyers should be educated to the fact that this increase in monthly mortgage payment in fact decreases their total out-of-pocket expenses over the life of the system, because the added capital costs are paid off entirely by savings in operations and maintenance. This added value for healthy house improvements will be true for anyone purchasing this house and will therefore justify a higher selling price necessary to recover capital costs.

The cost savings attributed to life cycle analysis of a healthy house can be difficult to calculate because of the variables involved. The risk for the

lender increases since energy and maintenance costs vary. (For example, a larger family may increase maintenance costs, and energy costs can vary from year to year.) On the other hand, insurance companies are able to establish the costs of complex scenarios to calculate such things as premiums for life insurance. Therefore, risk calculations for lenders should be possible. Utilities or government agencies could 'guarantee' this increased mortgage for energy conservation or efficiency measures as a transitional measure until a history of data produces lender confidence.

Another issue is that the present unpredictability in conventional energy supply and cost depends to a large extent on global economic and political activity. The extraction of a declining, non-renewable product from frontier sources that are increasingly difficult to access also results in higher costs. However, costs of future energy from local, continually renewable resources would be more stable and declining, and therefore help to rationalize the calculation of the cost of energy.

Subsidies now directed towards fossil fuel exploration and infrastructure could be redirected to make alternative technologies more affordable. Fuel subsidies to users are in fact indirect payments to oil and gas companies from public funds. They encourage the maintenance of higher prices and consumption.

Financial institutions or utilities could provide the means to mitigate the higher capital cost of original designs or equipment systems. For example, using fluorescent bulbs can save 10% to 15% on electricity costs. However, the high capital cost inhibits the conversion to energy-efficient bulbs. A program that rebates users at the time of purchase and recaptures the cost of the investment from utility bills could defeat this disincentive. With the high cost of electricity in the North, the recapture period without increasing power bills could be as short as eight months.²⁰

Affordability also depends on expectations. As mentioned before, it is difficult to affect expectations, except through education. Houses in Canada have become bigger while families have been getting smaller. From 1912 to 1989, the average house size in Canada increased by 30%.²¹ This trend is more rapid in the North and newer houses tend to be larger than earlier houses from 1950.²² Increased amenities – such as en suite or guest

²⁰ Calculations derived from information provided in *Green Home* (Camden House Publishing, 1993) and *Analysis of Utility Costs in Public Housing* (Yellowknife NT: Northwest Territories Housing Corporation, 1997).

²¹ *Green Home* (Camden House Publishing, 1993), p.93.

²² Examples of typical housing by Northwest Territories Housing Corporation (NWT HC) by year:

2000: NWT HC Home Ownership 3 bedroom, 932 sq. ft.

1970: Northwest Territories Rental Unit, 768 sq. ft.

1960: '512', 512 sq. ft.

1950: 'Matchbox', 300 sq. ft.

washrooms and space for home offices, separated dining, larger sleeping areas, clothes and equipment storage and on-site water storage – increase the size and cost of houses in the North. It is obvious that northern healthy houses would be more affordable if designs could make more efficient use of built space and if expectations were based on satisfying needs.

Issue:

Cost disincentives for newer technology

A capital cost disincentive exists for innovative concepts, materials and systems. High costs in the North are augmented by increased costs for amenities and more interior space.

Strategy:

Reduce lender risk and capital cost to users.

Reduce lender risk and capital cost to users through analysis of life cycle savings, education and creative programs or policies.

Reduce or remove disincentive subsidies and provide transitional policies to encourage alternative concepts that may have higher capital costs.

Design for multi-use and efficient spaces.

Design for shared or common spaces and various tenure or housing forms.

Provide information and education on capital and operational costs of increased built space efficiencies, and their associated savings.

Provide education on the real costs of overconsumption and the environmental imperative to reduce needs to a level of sufficiency.

2.3. Transportation

Transportation is currently the most important factor influencing the ecological sustainability of northern housing strategies. Because of the remote settings of most northern communities relative to where most building materials and current energy sources are manufactured or refined, freighting distances are large. Dollar costs are elevated because of the time involved and the high cost of fuel used in transportation over long distances, particularly when the only mode of freighting is by diesel truck or aircraft. Environmental costs are high not only due to the very high emissions that occur with air and truck freighting and the building and maintenance of highways, airports, and other associated infrastructure, but also because of the loss of choice, productive land to this infrastructure and its related components (e.g., parking lots and

filling stations; petroleum extraction, distribution and refining facilities). Freightings materials and energy over great distances significantly increases the embodied energy of a building. Social costs are high because the environmental costs of long distance and energy consumptive transportation deplete the ability of our land, water and air to support activities we normally engage in for our livelihoods, resulting in stresses on family and community health.

2.3.1 Local Materials

To the greatest extent possible, builders should use local materials for construction. However, in most cases in the North, local materials have not been developed. This major gap needs to be addressed by policy and economic development entities. In boreal forest, rough lumber should be developed as a renewable resource, building with stone should be explored and considered, and locally manufactured products should be pursued where there is a demonstrated sustainable opportunity. The manufacture of water tanks in the North is one example of how a government policy encouraged a local industry to develop.

2.3.2 Local Energy

A great need exists to develop small scale, renewable sources of energy. In many cases, fossil fuel energy is extracted in the North, shipped to the South for refining, and redistributed to the North for use. Not only does this strategy involve extreme dollar costs, it requires the use of tax dollars for subsidization,²³ and it results in gross levels of greenhouse gas emissions with associated environmental costs. A better solution is to create small-scale, renewable sources of energy – be they hydro, biomass, wind, solar, or hydrogen – and develop the associated expertise to maintain these. This strategy will avoid the full environmental and socioeconomic costs associated with fossil fuels, ultimately reducing these costs and contributing to local economies and community health.

2.3.3 Existing Materials

Many of the buildings in northern communities are constructed of very high-quality materials. For example, the calibre of wood products in many older buildings is superior to that in newer ones because prime wood was more

²³ This strategy can be considered a perverse subsidy because in supporting a non-renewable resource, it helps to inhibit the development of renewable resource alternatives. See Myers and Kent, *Perverse Subsidies: Tax Dollars Undercutting our Economies and Environments Alike*, 1999.

available during the time when they were constructed, or because costs were lower than they are today. Currently, when most buildings are slated for removal, they are simply demolished and taken to landfills. Thus, a key to yielding high quality construction resources and avoiding transportation costs is to recover and reuse these exceptional materials. Local initiatives should be encouraged to reclaim, salvage and store these materials for future use.

2.3.4 Regional Sources

In cases where materials and energy are not available locally, locate regional sources, or the closest sources, where they can be attained. Generally, transportation costs (calculated using FCA methods) are directly related to the distance and type of transportation employed. Therefore, consider the associated costs (FCA) of transportation when selecting materials and energy sources.

2.3.5 Railroad and Barge

When possible, use railroad and barge transport for all freighting, including that of building materials, operational and maintenance materials, and materials for recycling that cannot be achieved locally.

There is a great variation in environmental costs of different modes of transportation. By far the most costly forms of transporting freight in terms of FCA are aircraft and diesel truck. Less costly modes include barge and train. Dietrich Brockhagen calculated that air travel produces greater than seven times the greenhouse gas emissions than travel by railroad and boat.²⁴ The David Suzuki Foundation in 1999 reported greenhouse gas emissions of diesel trucks and trains by volume of freight and distance transported.²⁵ In 1995, trucks transporting 110 billion tonne kilometres emitted 30,000 Kt of greenhouse gases, compared to trains, which transported 279 billion tonne kilometres and emitted only 5500 Kt of greenhouse gases. Trains and barges are also the most likely forms of transport to adopt hydrogen fuel and fuel cells for power in the near future, because they are easily able to carry hydrogen. Fuel cells are considerably less costly (in FCA terms) than conventional engines.

²⁴ *Stop Climate Change*. Available at: <http://www.chooseclimate.org/>

²⁵ Data Source: Transport Canada, *Transportation in Canada*, 1998, and The Railway Association of Canada, *Annual Report and Railway Trends*, 1999, in David Suzuki Foundation, *Taking the High Road: Sustainable Transportation for the 21st Century*, 1999. Available at http://www.davidsuzuki.org/Publications/Climate_Change_Reports/

2.3.6 Transportation Schedule

By planning well ahead and by being flexible in the building schedule, transport requirements can be designed to permit use of the slower but less costly modes.

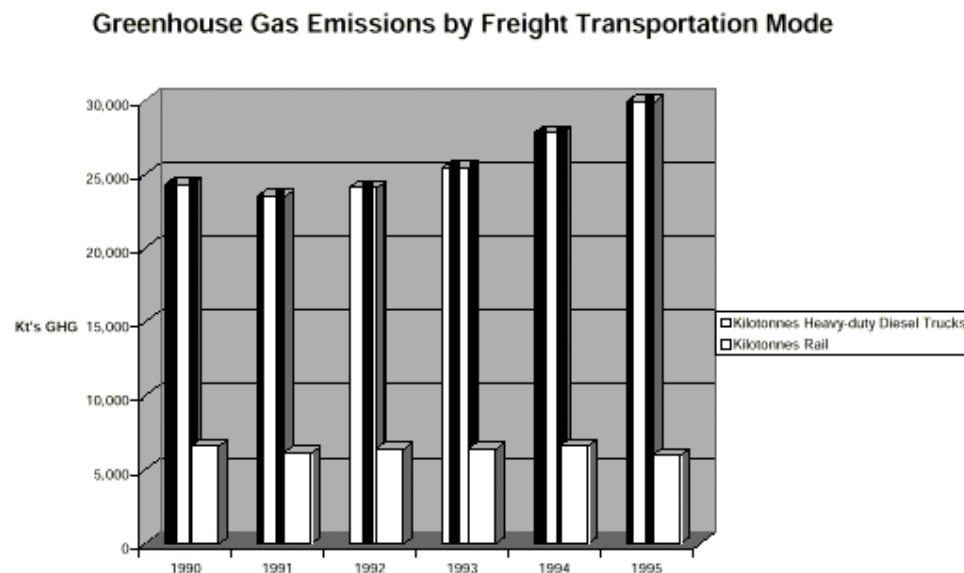
Issue:

Transportation is a key northern determinant of appropriate housing strategies.

Strategies:

Use local materials and energy to reduce the need for transportation.

Choose an energy-efficient method for transporting freight.



Source: Trends in Canada's Greenhouse Gas Emissions 1990-95

Data include emissions from all heavy-duty diesel trucks rated at a gross weight of more than 3,900 kilograms (excluding off-road use).

Figure X1. Volume of freight transported in Canada by rail versus truck.
Copied from David Suzuki Foundation, *Taking the High Road – Sustainable Transportation for the 21st Century*, 1999.

2.4. Fuel and Energy

Housing consumes energy in multiple ways, as operating energy and embodied energy. Operating energy is the energy used as fuel or power to heat (or cool) a house and run equipment and services. Embodied energy is the energy consumed in the manufacture and transportation of the materials used to build and maintain the house. Finally, the maintenance and replacement of materials or equipment during the life cycle of a house requires energy.

The use of fossil fuel to meet energy and heating requirements is extremely costly (in FCA terms), because this energy consumption has serious impacts on the environment. In the North, fossil fuel continues to be the primary source of virtually all energy consumption. Current energy sources for heating and powering homes in the North typically include diesel fuel, gas (e.g., propane, natural gas), large hydro and biomass. The energy used to operate buildings contributes to the emissions of carbon dioxide, sulfur dioxide and nitrogen oxides. Although various renewable and alternative energy technologies are readily available, with favorable economic impact, renewable and alternative sources of energy make up only a small portion of overall energy consumption.

Using an increased amount of renewable energy to heat and power homes will reduce dependency on energy imports in the North and reduce the depletion of non-renewable resources. Three other important strategies for reducing the consumption of non-renewable energy are choosing resource-efficient systems; planning for energy-efficient upgrades over the life cycle of the house; and reducing total energy consumption. Adopting these strategies will lead to a reduced impact of non-renewable energy sources on air pollution, global warming and ozone depletion. In view of these advantages, it is important to design buildings in keeping with these strategies.

1. Use renewable energy to meet an increasing proportion of heat and power requirements in homes.

Technology that uses renewal energy sources is currently available and the technology is being continually improved.

With the exceptions of hydro and biomass, there has been a tentative approach to employing renewable energy sources in North America, compared to Europe, Asia and other parts of the world. This is largely a result of substantial subsidies to the fossil fuel industry in North America.

In the North, subsidies are provided for the use of fossil fuel in remote communities and for residents directly. As long as such subsidies are in place, they will discourage the development of more efficient sources of

energy. For this reason, such subsidies are sometimes referred to as perverse. Resolving this situation requires removing these unreasonable subsidies, and at least temporarily redirecting some of the savings towards renewable energy development. Studies have already indicated the benefits that local economies would accrue from such activity.²⁶

The North needs programs to encourage small-scale development of renewable energy to meet the requirements of the community and individual buildings. Because most northern communities are located on exposed arctic coasts, large inland lakes, and substantial rivers, wind and hydro are likely the most appropriate technologies for immediate development. Solar energy should be tapped for appropriate seasonal demands. Fuel cell generators, appropriate in size for small communities and individual homes, have already been developed, many for testing elsewhere in the world. Fuel cell technology should be strongly pursued as an efficient alternative to fossil fuels in the North. Given the large costs of fossil fuel energy delivered to homes in northern communities, it is ironic that Canada's leading expertise in fuel cell development is being tested in foreign countries rather than in the Canadian North.

The builder of healthy homes should consider maximizing the use of renewable energy to meet power and heating needs. Renewable energy such as solar, wind and hydro are available everywhere; therefore, their use avoids costly (FCA) imports.

Wood energy is an important source of heating in the forested regions of the North; its use should be encouraged and supplemented with good information on the most efficient means of heating with wood. Trees store carbon dioxide, so as the volume of live, standing wood increases, carbon dioxide is captured from the atmosphere. Therefore, as long as new forest growth produces wood at the rate that it is being harvested for combustion, and assuming other ecological concerns are addressed, the carbon dioxide contributions from wood combustion are effectively zero. This is so because the carbon dioxide produced through combustion is recaptured in the form of replacement wood, as opposed to entering the atmosphere and contributing to climate change. Thus, wood heat can be an efficient, low-cost (FCA) fuel.

2. Choose resource-efficient systems.

To the extent possible, choose systems that are resource-efficient and compatible with heating and power supplies from renewable energy sources. The systems for selection include the building envelope, water and sewage

²⁶ E.g., Pembina Institute for Appropriate Development. *Lost Opportunities: Canada and Renewable Energy – A Cross-Country Comparison of Government Support for Renewable Energy*, September 1999.

systems, space heating, appliances, lighting and systems for air exchange and humidification.

Materials and resources used to operate and maintain a house over its lifetime are much greater in embodied energy than are the resources used in constructing the house. In recognition that a large part of the costs of a house occur during its ongoing operation and maintenance, carefully consider and choose service systems that minimize these costs. Strategies include providing efficient electric lighting, maximizing mechanical system performance and using efficient equipment and appliances.

3. Plan for maintenance and replacement of systems and flexibility in the use of space.

Over the life of the house there may be opportunities to bump up efficiencies by replacing old systems with new ones, or changing the use of space as occupants change over time. Planning for these eventualities can lead to increased resource efficiency and convenience in maintaining, updating and living in the house.

4. Reduce the total energy consumption loads of buildings.

At the site design stage, optimizing building placement and configuration can help to reduce energy consumption loads. Select a site with potential for energy conservation. Consider solar access, topography and wind patterns.

Optimizing building envelope thermal performance will also reduce overall energy consumption loads. Evaluate the day lighting implications of the site, i.e., solar access and seasonal variances, to facilitate the integration of day lighting into the design.

Finally, conserving energy during the life of the building will also decrease energy loads.

2.5. Regulations and Policy

All regulations naturally tend to favour conventional and proven materials, systems or methods. This is also true in the North. However, many regulations in the North are adopted in whole or with minor modifications from standards set in southern jurisdictions. Therefore, the imported regulations are sometimes at odds with the northern reality.

Two basic categories of regulation can be defined. One type is national codes or the territorial adaptation of national standards. These regulations cover materials, technical systems and public safety issues. In the North, these regulations also apply to land use in areas of federal jurisdiction. The second layer of regulations are those generated by a community, or having

some local or community control. These regulations include land use, zoning, community standards and development issues.

2.5.1 National Standards

All building in the North is regulated under the National Building Code. In addition, at this time, all communities have some kind of development plans in place. The level of enforcement of the code and regulations varies depending on local resources and the size of the project. The use of unusual materials, assemblies or products will result in more regulatory difficulties than in the South. In the North, it will be extremely difficult to gain approval because of the impracticality of testing alternatives and the unavailability of qualified authorities. The application may be attractive in order to reduce the high costs of subsidization by the Government of Canada but the market is small. Manufacturers of materials with new, alternative applications will not generally spend the time or money to receive national certification for such a small market. This is especially true for standards involving fire, health, and safety. Once a national standard (or a territorial standard based on the national one) is adopted, it becomes very difficult to propose an alternative, even when it has been ruled safe or healthy by other jurisdictions. Because of issues of insurance liability, these types of requirements are particularly resistant to change. A complex, supranational and interrelated group of associations exist – including government, manufacturers and insurance agencies – that screen, test or standardize materials, equipment and processes. Inspectors look for equipment and products that have CSA, CGCB or other standard approval numbers.²⁷ For example, new, integrated mechanical systems or heating stoves may not have been tested. Inspector approval (i.e., by a government authority) may be necessary to obtain builders', fire, liability or other insurance.

It is convenient and practical for small, local administrations to adopt national or territorial standards. However, liability generally does not reside with the inspecting agency, since administrations are reluctant to accept any responsibility. In larger projects, engineers or architects could offer design responsibility for innovative systems, but this would not extend to smaller

²⁷ A partial list of major issuing agencies designated by the National Building Code of Canada 1995 includes the following:

CGSB: Canadian Government Standards Board; CSA: Canadian Standards Association; ASTM: American Association for Testing and Materials; NFPA: National Fire Protection Agency; UL: Underwriters Laboratories; ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.; ANSI: American National Standards Association; AWWA: American Wood Preservers Association; NLGA: National Lumber Grades Authority; TPI: Truss Plate Institute; SMACNA: Sheet Metal and Air Conditioning Contractors National Association.

projects or issues of health or safety not related to the building structure or operation.

Issue:

National standards may be difficult to meet or not relevant. Compliance with issuing agencies is required in most cases.

Strategy:

**Review standards acceptable in other jurisdictions.
Examine the relevance of agency standards.**

2.5.2 Community Standards

Local control of community standards and regulations depends on the size of the community and its political structure. In the NWT, the Department of Municipal and Community Affairs (MACA) provides land use and development control, such as zoning, to most of the smaller communities. Larger communities with some tax base develop their own plans. Zoning and similar controls are part of a community or regional administration. These regulations often refer to land use, density, aesthetic character and existing conditions. They may also address parking requirements, setbacks and easements, and height limits. Material and design guidelines also exist.

In some places, the regulations govern more intangible qualities of neighbourhood character that rely on public perceptions and local desires for their support. These regulations are often closely tied to controlling the financial value of a property. For example, through their regulations, jurisdictions can address aesthetic concerns such as lawns, fences and materials. Unlike the large administrations in the South, in the North there is in general more flexibility in these controls, with the possible exception of a few larger northern centres. Local politicians, building authorities and residents can usually be made aware of viable alternatives. However, the implementation of these plans may become more difficult if national standards become an issue. In the past these standards have been set with little local input and often have been based on models used in southern, non-Native communities.

Issue:

Local standards

Local standards can be a barrier to innovation. Community regulations are sometimes of non-local origin or unnecessary for local realities.

Strategy:

Encourage progressive decisions at the local level.

1. Educate local authorities and community leaders on the viability and legitimacy of alternatives.
2. Encourage the use of existing flexibility at the local level.
3. Encourage the exercising of local decision-making.

2.5.3 Water Regulations

Water regulations in the North need to become more flexible to allow more sustainable water management practices. However, issues of environmental conditions, public perceptions and availability of skilled technicians need to be considered. Because of high servicing costs and remoteness, the North would be a prime area for the application of technology for water conservation or recovery systems and wastewater treatment. These systems may be technically feasible but require the modification of plumbing and health codes to gain wider application. Regulations will need to be changed as these systems prove their effectiveness. The public also needs to be educated about alternatives. Some communities have had experience with piped hot and cold water on demand for only one generation. Running water is convenient, it raises levels of health and it is a tangible sign of technical and personal progress. Therefore, residents and community officials are reluctant to embrace systems that are not yet proven in the North. Reductions of the allowable standards for potable water may not be perceived as progress. For instance, low water or no-water composting toilets may seem like a 'step backwards.' This can be a sensitive issue when the 'step forward' was so recent.

Local conditions and technical knowledge also need to be considered. Claims made for systems tried elsewhere may not be applicable and should not be accepted in the North. Cold weather and poor soil make exterior septic systems or compost impractical in many areas. Environmental conditions are very harsh and skilled installation, service or repair is not always easily available. The resident may not have the commitment or knowledge to become the operator of a novel technical system.

Nevertheless, it is important to encourage alternative water management systems as residents develop the commitment and knowledge to assume greater responsibility for management of household potable and wastewater, and as their attitudes towards this technology improves. A standard has developed in western society over the past century to provide centralized sewer systems. Users connected to the system have little awareness of the effects that the indiscriminate use of various household chemicals and toxins

has on the environment. On-site wastewater treatment, whether composting or septic, necessitates environmentally sensitive wastewater management.

Issue:

Public acceptance

Public acceptance needs to be gained for no-water or low water toilets and re-circulated water for non-potable uses.

Strategy:

Educate the public on water-saving technologies.

Encourage the development of low-maintenance water-saving systems that are locally and culturally appropriate.

Issue:

Technical and health requirements

Technical and health requirements for water-saving and re-circulation systems can inhibit their development.

Strategy:

Develop reasonable regulations for water-saving technologies.

Examine manufacturers' or engineers' liability.

2.5.4 Power Regulations

In theory, decentralized, local power sources are ideal for a dispersed population, since they reduce the amount of energy that would be lost through transmission. No large-scale electrical grids exist north of the 60th parallel. Since most power is already distributed at the community level, the potential exists to change to alternative energy sources that are locally produced. However, the generation of small amounts of power by homeowners or communities can be a problem for electrical power regulators. This type of power raises many issues, such as stability of current flow, metering and billing, long-term planning and utility standards. Local power generation from the sun or wind can be seasonal and uncoordinated with demand. Technical challenges such as power storage and delivery have been under study in other areas and should not prohibit the development of local power production. Instead, regulations should be introduced to promote the development of alternative, renewable energy sources locally. As with

water, users need to learn how to manage their power consumption, to increase efficiencies, decrease peak loads, and acknowledge daily and seasonal patterns of availability.

Issue:

Current regulations inhibit self-produced power.

Current regulations do not address self-produced power. Without standards to address the many issues for adopting alternative energy sources, there are no incentives or encouragement to adopt these newer systems.

Strategy:

Develop reasonable regulations. Allow for self-produced power.

Address the following considerations in regulations.

- stability of current flow

- metering and billing

- long-term planning

- utility standards for community utilities

- seasonal power production (e.g., solar and wind power)

Develop regulations for creating and storing self-produced power, as well as distributing it (i.e., sending power back to an electrical grid or utility).

Create incentives to encourage self-produced power, such as passing savings (generated from more efficient servicing) on to consumers.

2.5.5 Heating Regulations

Current heating regulations can prohibit the use of renewable resources, such as wood, as a main heating source. Wood stoves are often used as a primary or secondary heat source in the North. Biomass is a local resource and can be managed to be renewable. Wood is an economically viable resource and its supply can also be pursued as a community or family activity. Though it need not be so, emissions from biomass can be an issue when combustion is inefficient (see Section 2.4). New technical equipment can integrate the energy systems in a house. These include water and space heating, heat recovery ventilation, and conventional fossil fuels combined with biomass and/or solar heat gain and heat storage. The existing technical standards for heating, plumbing and electricity can make integration difficult. In the North the common use of biomass as a heat source complicates this situation.

Issue:

Technical and regulatory requirements for integrated and biomass systems

Strategy:

Allow for flexibility and exceptions if possible. Accommodate owner responsibility in non-critical circumstances. Examine the acceptance of manufacturers' or engineers' standards as grounds for liability insurance.

2.5.6 Area Development

Planning for the development of groups of houses or subdivisions is controlled by conventional infrastructure standards, such as site servicing, road design, water management and emergency access. Changes in these regulations are generally only possible if the servicing results in cost savings for the public. Currently, the up-front costs to achieve these savings tend to be transferred in part to the homeowner as an increase in capital cost for alternative equipment. Some of the cost savings should be returned to the homeowner, for example as a reduction in servicing fees or taxes.

Alternative community design approaches are more feasible in the North because the potential savings associated with these approaches are even greater when compared to the typically higher costs for development and site services.²⁸ However, such developments would raise some administrative questions: What are the development fees or taxes on a building that is unconnected or semi-connected to services? And what happens if services are required later at a higher cost?

Issue:

Changes in the delivery of public services

Changes to the provision of servicing for groups of houses or subdivisions would involve fundamental changes to the current space requirements and regulatory structures for road design, emergency access, etc. In addition, capital costs of acquiring innovative systems can be prohibitive for the homeowner.

²⁸ *Analysis of Utility Costs in Public Housing* (Yellowknife NT: Northwest Territories Housing Corporation, 1997).

Strategy:

Revise regulations to accommodate alternative models of servicing.

Develop administrative and legal formulas that accommodate alternatives to standard servicing models.

Promote financial structures that return savings from more efficient servicing to the homeowner.

Build flexibility into long-term planning, in case services are required later.

2.5.7 Site Development

At the scale of the individual building site, planning becomes an intimate process that involves the needs of users and the characteristics of the site. When we call something 'a site,' we are asking it to exhibit the characteristics we need for what we have in mind. It is a 'good site' if it seems to fit a kind of preconception. Alternatively, if it is referred to as 'land' or even 'the land,' we will often consider a broader context. Obviously, proximity to existing services or personal community is an important characteristic of the land. This discussion of land and user should take place for any successful housing plan. However, it becomes even more critical if one plans for more responsible or healthier houses. Strategies of sustainability and effective planning need to be applied first at the level of the site and user. Problems occur when these strategies conflict with existing regulations or financial procedures. This is more critical for smaller communities, but when possible, it should be practiced in bigger centres, where complex service structures exist. The actual user is not always known. In that case one must work within the understanding of a community.

If housing is conceived and formulated in isolation from the community, the user or the land, it will represent a failure of understanding. Considerations of energy use, user needs and cultural appropriateness are key. Some technical ideas will require more community or user involvement to maintain than others. There can be a tendency with advanced housing to use sophisticated materials or systems, whether or not they are necessary. At its worst, this practice can result in 'spaceship' houses that are part of a technotopian daydream. These are houses that clearly do not belong on the site or in the community. Housing like this will increase the level of personal and community alienation and lead to increased social costs. Instead, any technologically advanced features need to be assessed for their local appropriateness and usefulness.

Issue:

Characteristics of the site and needs of users

Too often, the building site is considered as an isolated patch of land, disconnected from the larger environment and from the user who will occupy it. Northern Healthy Housing instead demands an interrelated approach that addresses principles of sustainability and effective planning at the level of the site and user.

Strategy:

Understand the needs of users and the characteristics of the site.

Consider 'the land' in a broad context.

Apply strategies of sustainability and effective planning at the level of the site.

Use materials and systems that are culturally and technologically appropriate.

Get to know the community and its needs.

2.5.8 Remote Buildings

There are no separate standards for remote buildings in the North. This can result in trying to administer codes in conditions for which they were never intended. Remote cabins or houses cannot easily meet existing codes and arguing for alternatives often only highlights issues of noncompliance. Fire and safety regulations often assume some proximity to emergency services. This is not the case for remote buildings. Alternative solutions may provide an increased level of safety but cannot comply with national fire or health standards.

Issue:

Impractical or inappropriate application of codes to remote housing

Strategy:

Develop standards for rural housing.

Develop local and specialized rural standards.

Develop applicable exceptions to ensure safety in remote locations. Look at examples from other jurisdictions.

Part Two: Technology and Information Resources

3. Materials and Technology

3.1. Introduction: Integrated Approach

In the twentieth century, the world made giant strides in technological achievements and population growth, with corresponding increases in resource use. The combined side effects of both are pollution, toxic waste, global warming and resource depletion, to the point where the earth's ability to sustain itself is threatened.

The resources needed to create, operate and replenish housing infrastructure are enormous and diminishing. For example:

Raw material extraction leads to resource depletion and losses in biological diversity.

The manufacture and transportation of building materials consumes energy and contributes to global warming.

Waste generation adds to landfill problems.

Unhealthy indoor air quality leads to 'sick building syndrome' and increased mortality.

The impact of a house on natural resources is evident beyond the building's immediate location, as housing development affects watersheds, air quality and transportation patterns.

The design, construction and operation of housing often fail to take into account the interrelationship among building siting, design elements, energy and resource factors, building systems and building function. It is important to consider an integrated design approach to account for the effect the various factors have on each other. As reviewed earlier, climate, site orientation, building envelope, system choices, economic guidelines and occupant use are all factors needing consideration in the integrated approach.

Consequently, there is a growing need for housing policy-makers, planners, suppliers, builders and owners to change the approach to design, construction and operation of housing, adding environmental performance as a new value.

The objective of the integrated approach is one of housing as a complete system where the building orientation, form, envelope, systems, materials and contents interact together. The result is a building that will perform as a resource-efficient and cost-efficient dwelling, and that will enhance the occupant's productivity and well-being.

This section presents technology choices that are resource-efficient and create a healthy, comfortable, non-hazardous space for occupants. The information presented is not intended to be conclusive or definitive. Rather, it is an introduction and general guide regarding resource and energy efficiency and material-related health issues.

Ecologically sustainable building is achieved by allowing awareness of the issues to pervade every stage of development and decision-making in building a house. Planning a reasonable construction schedule avoids costly actions and poor choices by allowing plenty of time for decisions when the unexpected happens. Proper site selection and orientation of a house entails the preservation of environmentally beneficial qualities of the land and natural habitat, while optimizing passive solar effects, shelter from wind and seasonal shading, and considering water and sewage services. Addressing issues of resource efficiency and sufficiency requires considerations of space, water, energy and the need to minimize waste. It also requires a plan to recycle and reuse materials during operation and maintenance and at the end of the life of the house. Selection of suitable materials requires considerations of LCA, embodied energy and FCA. For example, to minimize 'real' (FCA) costs, design the house and its maintenance keeping in mind the availability of local materials and expertise. When considering LCA, choose materials that will be resource-efficient over time during future maintenance and upgrades to a home.

To work towards a sustainable northern healthy house, it is necessary to determine appropriate material choices in line with the concepts of LCA, embodied energy and FCA, described in Section Two. These overriding concepts need to be addressed throughout all stages of a building's planning, construction and life cycle. The following key aspects of material selection should be considered as they relate to these concepts.

3.2. Site Design

The arrangement and orientation of buildings on a site should acknowledge any pre-existing natural elements and should consider the site characteristics that influence sustainable design, such as solar access, topography and air movement patterns. Site planning should not impose a building design on the site. Instead, the ecological characteristics of the site should dictate its' use. This approach lessens the impact of human activity and preserves the natural elements of the site. It can also enhance human comfort and health, and link people both physically and socially. The ideal is site design in which the arrangement of access, buildings and common use harmonizes with the larger macro-environment, with consideration for existing historical and cultural patterns of the community.

3.2.1 Site Conditions

Sustainable principles should be used for analyzing and assessing site conditions, and for informing decisions of site development, building orientation and layouts. Important characteristics that influence building design include the following.

- latitude (solar altitude)
- micro-climate factors (i.e., wind loads)
- topography and land form
- solar access
- surface and sub-surface conditions
- air movement patterns (annual and diurnal)
- characteristics of the climatic zone
- potential natural hazards (e.g., flood, winds, slides)
- flow patterns for pedestrians, traffic and services

3.2.2 Building Orientation

An analysis of site conditions can inform building design that addresses energy efficiency and responds to its climate in a number of ways. Housing can be oriented and designed to achieve the following benefits.

- take advantage of solar energy for passive and active solar systems
- minimize north wall heat loss
- take advantage of natural ventilation
- minimize snow accumulations at entryways
- optimize day lighting

By considering sustainable principles at the site design stage, the builder of a healthy house can maximize opportunities for energy efficiency in the design of housing.

3.3. Materials

Many building materials are much more costly in terms of full cost accounting than others; therefore designers and builders should carefully select materials using materials assessment tools that rate life cycle accounting, embodied energy and full cost accounting.

3.3.1 Builders' Reference

It is almost impossible for a home builder to independently develop his or her own conclusions about the embodied energy of each material used in building a house. Fortunately, there are an increasing number of resources available for ecologically sustainable building practitioners. Resources include experienced people, books and catalogues, Internet Web sites listing sustainability assessments of materials, and 'green' building checklists for assessing building materials and systems used in homes. A number of these references are listed in the resource section (Section 4) of this report.

Use building materials made from renewable resources when you can, but be aware of some cautionary notes. Renewable resources can be overexploited – harvested beyond the optimum sustainable rate – so pay attention to the sustainability of resources being considered. In the case of wood products, many forestry operations are now choosing to have their products certified under the Forest Stewardship Council certification program.²⁹ This program has not yet become operational in the Canadian North, but it will likely happen in the future.

Strategy:

Encourage the local development and manufacture of building materials.

Assess regional resources and encourage small-scale, local development.

Assess regional resources for the potential to meet the needs for building materials, and encourage small, local business development to meet these needs.

Limitations are developing on the availability of some building material resources. As the availability of raw resources declines, costs increase. Many building materials consume large amounts of energy and resources to manufacture. Many building materials have a relatively short useful life, requiring continual maintenance and expensive replacement. The disposal of replaced building materials requires extensive landfills.

3.3.2 Selection Criteria

Consideration should be given in the selection of materials to those with resource efficiency (those that are sustainable, reusable and recyclable, with

²⁹ www.fsus.org

low embodied energy to manufacture and transport) and with properties that create a healthy, non-hazardous space for building occupants.

1. *Consider the following when selecting materials.*
 - a. *Resource quantity*
 - b. *Reused materials*
 - c. *Recycled materials*
 - d. *Use materials that foster sustainable management practices.*
 - e. *Consider material sources that reduce transportation.*
 - f. *Use regionally appropriate materials if available.*
2. *Consider life-cycle costs; higher initial costs are often justified by future avoided costs.*
3. *Use materials that have future resource recovery or recycling potential.*

3.3.3 Material Categories

The following types of building materials and systems are good choices for their resource efficiency and positive effects on health.

1. *Divisions 3 and 4: Concrete and Masonry*
 - a. *Resource efficiency*
Consider the following materials.
 1. *Recycled aggregates*
 2. *Low-waste formwork*
 - b. *Health and pollution*
 1. *Air pollution emissions from concrete are low.*
2. *Division 5: Metals*
 - a. *Resource efficiency*
Consider the following materials.
 1. *Steel with recycled content of 30% or greater, which is readily available*
 2. *Aluminum with recycled content of 20% or more, which is derived from recycled consumer product containers*
 3. *Architectural metalwork from building salvagers*

- b. *Health and pollution*
 - 1. *Indoor air pollution is minimal with metal products.*
- 3. *Division 6: Wood and Plastic*
 - a. *Resource efficiency*

Consider the following materials.

 - 1. *Domestic wood produced through sustainable forest management practices*
 - 2. *Engineered and value-added wood products made from small diameter, fast-growing trees that have low-grade fiber*
 - 3. *Salvaged timber and wood products*
 - 4. *Sheathing materials made from post-consumer recycled materials, i.e., newsprint and wood fiber*
 - b. *Health and Pollution*
 - 1. *Avoid engineered wood products that have substantial indoor air pollution emissions from their adhesives and binders.*
 - 2. *Consider engineered wood products made with phenolic resins and urethane adhesives.*
- 4. *Division 7: Thermal Insulation and Moisture Protection*
 - a. *Resource Efficiency*

Consider the following materials.

 - 1. *Mineral fiber insulation primarily made from basalt rock or steel mill slag*
 - 2. *Glass fiber insulation with 30% or more post-consumer recycled glass content*
 - 3. *Cellulose insulation containing 70% post-consumer paper waste*
 - 4. *Foamed polystyrene insulation with post-consumer recycled content. Expanded polystyrenes are made with a steam process and non-chlorofluorocarbon (non-CFC) gas.*
 - 5. *Urethane foams made with non-HCFCs*
 - 6. *Vermiculite and perlite, naturally occurring minerals that can be used for loose fill insulation*
 - 7. *Metal panels for roof cladding. Very little material covers a large area and is both durable and recyclable.*
 - 8. *Composite shingles made with recycled content*

b. Health and pollution

- 1. Mineral and glass fibers are recognized as possible carcinogens, requiring care when handling.*
- 2. Cellulose fiber is relatively safe, but does contain borates and sulfates as fire retardants and stabilizers, requiring care in handling.*
- 3. Vermiculite and perlite dust are dangerous if inhaled and need to be handled accordingly.*
- 4. Plastic insulations release gases such as styrene and are flammable, producing toxic gases when burning.*

5. Division 9: Finishes

Gypsum Products

a. Resource efficiency

Consider the following materials.

- 1. Gypsum board with at least 10 to 15 % recycled content*
- 2. Paper facings made from recycled paper*

b. Health and pollution

- 1. Gypsum products are minor indoor pollutants.*
- 2. Gypsum surfaces are sinks that absorb other pollutants. Consider surface finishes to minimize the absorbent nature of gypsum.*

Composite Wood Panels

a. Resource efficiency

Consider the following materials.

- 1. Hardboards, which are durable and resource-efficient*
- 2. Particle board and medium density fiberboard (MDF) made with phenolic resins, which are resource-efficient.*
- 3. Low density fiberboards made from paper and wood fiber with up to 100% recycled content*
- 4. Veneer wood panels with hardwood facings made with phenolic resins, which are resource-efficient choices for interior finish work*

5. *Fiber-reinforced cement boards made with recycled fiber as substrates for tile and decorative finishes*

b. Health and pollution

1. *Engineered wood products made with phenol formaldehydes have low formaldehyde emissions.*

High Pressure Laminates

a. Resource efficiency

1. *No manufacturers at this time offer substantial recycled content in their product.*

b. Health and Pollution

1. *Emissions from glues used for installation can be quite high. Therefore, having the work done off site is desirable if possible.*

Ceramics

a. Resource efficiency

1. *Consider tiles made with recycled content up to 70%.*

c. Health and Pollution

1. *Cement mortars (modified with acrylic additives) are very safe products to handle.*
2. *If ceramics are used in conjunction with coves and bases having flexible joints, choose low-solvent content adhesives, such as acrylic.*
3. *Avoid epoxy modified grout, which contains hazardous components.*
4. *For porous tiles choose sealers that have low volatility, i.e., acrylic or water-based silicone types.*

Wood Flooring

a. Resource efficiency

Consider the following materials.

1. *Salvaged solid wood flooring*
2. *New wood flooring material made with composite or plastic laminates, which are resource-efficient.*
3. *Domestic hardwoods that come from sustainable management forest practices*
4. *Floating floor techniques that make wood floors easily removable*

b. Health and Pollution

- 1. Factory finished products avoid on-site sanding and finishing, providing better air quality.*
- 2. For sanding performed on site, carefully seal off the area.*
- 3. For finishing on site, consider using water-dispersed urethanes with low-volatility content.*
- 4. For glue-down floors use low-volatility content glues.*

Resilient Flooring

a. Resource efficiency

- 1. Consider real linoleum – it is made from a variety of renewable materials and is highly durable.*

b. Health and pollution

- 1. Resilient flooring products produce some air pollution emissions.*
- 2. Choose low-volatility content glues and maintenance products such as waxes and sealers.*

Carpets and Underpads

a. Resource efficiency

Consider the following materials.

- 1. Polyester carpets made with recycled content from ethylene terephthalate (PET) containers*
- 2. Wool carpets, which are a renewable material having inherent fire resistance*
- 3. Carpets made with Nylon 6 fiber, having a high level of recyclability*
- 4. Underpads made from rubber products, which are resource-efficient*

b. Health and pollution

- 1. Carpets made with synthetic latex resin are a source of air pollution, especially 4 phenylcyclohexene (4PC), an irritant identified as contributing to Sick Building Syndrome.*
- 2. Carpets made with fusion bonding eliminate latex and have low indoor pollution potential.*

Paints

a. Resource efficiency

Consider the following materials.

- 1. Paints made with recycled content, made by remixing leftover manufactured product and consumer returns (offered by several paint manufacturers)*
- 2. Paints containing very little toxic solvent*
- 3. Water-borne acrylics, rather than alkyd-based paints*

b. Health and pollution

- 1. Avoid paints containing lead, mercury, hexavalent chromium and cadmium. Check MSD sheets carefully.*
- 2. Select paints for the least volatile emissions.*
- 3. Consider water-dispersed acrylics and latex products.*
- 4. Consider paints certified to environmental standards.*

3.4. Building Envelope

The building envelope comprises the structural materials and finishes that enclose space and separate the inside from the outside. The building envelope is a compromise that balances requirements for ventilation and natural light with the necessity of thermal and moisture protection appropriate for the local climate.

Strategy:

Design an efficient thermal envelope by avoiding thermal bridges. Ensure proper air barrier and moisture retarders.

3.4.1 Envelope Design

Assess the local climate to determine the appropriate envelope materials and building design.

- 1. Site condition and building envelope*
 - a. Design wind-tight and well insulated building envelopes.*
 - b. Assess the site's solar geometry.*

2. Building shape and orientation

- a. Consider the most compact building footprint and shape that will work with other considerations of the site and occupant use.*
 - i. Consider that the greater ratio of exposed exterior building surface to volume of enclosed space, the more the building will be influenced by heat exchanges at the skin surface.*
 - ii. A square floor plan design is more efficient than a rectangular one because it contains less surface area for heat loss, but may not be the most efficient design when other considerations are factored in, such as day lighting, passive solar access and occupant use patterns.*
- b. Orient the building to minimize the effects of winter wind turbulence upon the envelope.*
 - i. Consider the site-specific microclimate.*
 - ii. Consider the potential of wind turbulence to affect air infiltration through the building envelope.*

3. Doors, windows and openings

- a. Consider natural daylight, heating and ventilation strategies when sizing and positioning doors, windows and openings in the building envelope.*
 - i. Windows utilized solely for view need not open, whereas windows used also for ventilation must do so.*
 - ii. Windows placed for daylight should be placed high on the wall to bring light deeper into the interior space and eliminate glare.*
 - iii. Design vestibules at building entrances to provide airlocks that prevent loss of heated air to the exterior.*
- b. Consider double or triple glazed windows with a high 'R' value and appropriate shading coefficients.*
 - i. 'R' value is a measure of resistance of heat flow across a wall or window assembly (higher values represent lower heat loss).*

- ii. *Shading coefficient is a ratio used to compare different heat reducing glass. The shading coefficient of clear double-strength glass is 1.0. Glass with a shading coefficient of 0.5 transmits one-half of the solar energy that would be transmitted through 1.0 glass.*
- c. *Consider glazing coatings for windows.*
 - i. *Metallic coatings and tints either absorb or reflect specific wave lengths in the solar spectrum. Thus, excess heat can be reduced while providing abundant daylight.*
 - ii. *Where solar gain is desired consider the appropriate coatings for the glazing.*

4. *Thermal efficiency*

- a. *Design walls, roofs and floors for adequate thermal resistance to provide human comfort and energy efficiency.*
 - i. *Avoid insulating materials that require chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs) in their manufacture.*
 - ii. *Consider insulating materials made from recycled material.*
 - iii. *For framing systems using thermally conductive materials, consider insulating sheathing to reduce thermal bridging.*
- b. *Prevent moisture buildup in the building envelope.*
 - i. *In certain conditions, water vapor condenses within the building envelope. If the insulating material gets wet it loses its' insulating properties and accelerates deterioration on materials comprising the building envelope. Prevent moisture buildup by using appropriate building envelope systems that allow adequate ventilation and moisture protection.*
- c. *Prevent convective heat loss through the building envelope. Convective losses occur from wind loads on the exterior walls. Occupants feel the effects of convective heat loss as drafts.*

- i. *Consider careful detailing, sealing and weatherstripping to eliminate sources of convective heat loss.*
- d. *Select building materials that reduce heat transfer. Heat transfer occurs as either conductive, radiant or convective losses or gains.*
 - i. *To reduce thermal transfer through conduction, design details to eliminate or minimize thermal bridges.*
 - ii. *To reduce thermal transfer through convection, design details to minimize infiltration or exfiltration. Consider sealants with low environmental impact that do not compromise indoor air quality.*

3.5. Building Systems

Building systems designed for air delivery, heating, lighting, and electrical and plumbing systems must accommodate a variety of design practices, including glazing, air-tightness, artificial lighting and appliances. As the need for capable building systems has increased, their designs have improved. However, they have also become more dependent on fossil-fuel energy sources that have gradually replaced natural energy flows such as climate, temperature and solar conditions.

Strategy:

Design building systems to meet the occupant's needs through the most efficient and environmentally positive means, with consideration for climatic conditions, use of space and building technology.

In the design, consider solar orientation, floor plan, thermal mass, placement of windows and doors and natural ventilation.

Heating and ventilation requirements are affected by the interrelated characteristics of the building, including passive solar design elements, occupant equipment and heating loads.

3.5.1 Building System Design

1. *Consider the following solar strategies and opportunities for energy efficiency.*

- a. *Integrate the building envelope design with solar strategies such as glazing and day lighting.*
- b. *Design the floor plan and orient the building to maximize energy benefits.*
- c. *Utilize thermal mass to maximize energy benefits.*
- d. *Optimize energy gain benefits with appropriate glazing selections, sizing and locations.*
- e. *Optimize the use of natural daylight to reduce artificial lighting requirements.*
- f. *Consider architectural elements such as vertical and horizontal shades to reduce direct radiation when solar gain is not desired and to reduce conductive heat loss when desired.*

2. Air Delivery Systems

- a. *Consider passive air systems using natural ventilation.*
- b. *Consider a variable air volume system to reduce energy use.*
- c. *Reduce duct system pressure losses. Round or flat oval duct shapes will reduce energy losses.*
- d. *Use ductwork with smooth internal surfaces to reduce energy, dust buildup and microbial growth.*
- e. *Consider using low velocity coils and filters to reduce energy loss through each component.*

3. Heating Systems

- a. *Consider locally available energy sources for heat generation, such as the following.*
 - i. *Passive and active solar systems*
 - ii. *Wood*
 - iii. *Fuel oil*
 - iv. *Natural gas*
 - v. *Electricity*
- b. *Consider heat distribution systems.*
 - i. *Passive distribution with convective air movement*
 - ii. *Central forced air delivery through fans, ducts and diffusers*
 - iii. *Hydronic distribution through unit heaters, perimeter radiation and in-floor radiation*
 - iv. *Thermal storage, i.e., water, thermal mass, phase change*

- c. *Consider the heating appliance.*
 - i. *Space or unit heaters*
 - ii. *Multiple fuel appliances, i.e., wood/fuel or oil/electric*
 - iii. *Combination units – e.g., integrated space heating and domestic hot water*
 - iv. *Forced air furnaces*
 - v. *Water boilers – consider low mass units to reduce standby heat loss*
 - vi. *Cogeneration systems, i.e. fuel oil, turbine gas or fuel cell*

4. *Electrical Systems*

- a. *Distribution*
 - i. *Consider photovoltaic systems.*
 - ii. *Consider cogeneration systems.*
 - iii. *Consider two-way meters where available.*
- b. *Lighting systems*
 - i. *Consider the maximum use of natural daylight.*
 - ii. *Design building orientation and envelope to achieve daylighting contribution.*
 - iii. *Design to maximize the use of reflected light.*
 - iv. *Incorporate the most energy efficient technology for lamps and fixtures, such as the following.*
 - 1. *T8 fluorescent lamps*
 - 2. *Compact fluorescent lamps*
 - 3. *Halogen lamps with infrared reflectors*
 - v. *Maximize the use of task lighting.*
- c. *Appliances*
 - i. *Consider energy efficient and environmentally sound appliances.*
 - 1. *Passive and low energy-use refrigerators*
 - 2. *Low-volume dishwashers*
 - 3. *Low-volume clothes washers*
 - 4. *Drying closets*

5. *Plumbing systems*

- a. *Hot water heating*
 - i. *Consider passive and active solar systems.*
 - ii. *Consider on-demand systems.*

- iii. *Consider combination space heating/water heating systems.*
 - iv. *Reduce hot water standby losses by the following means.*
 - 1. *Tank insulation*
 - 2. *Anti-convection valves*
 - 3. *Small heaters with high recovery rate*
- b. *Water systems*
 - i. *Use low-flow plumbing fixtures.*
 - ii. *Design efficient plumbing system layouts.*
- c. *Waste water systems*
 - i. *Consider composting toilets.*
 - ii. *Consider on-site waste water treatment.*
 - iii. *Recycle water for non-potable use.*

3.6. Water Conservation

Issue:

The amount of water available on the planet is finite.

As the world's population grows, the amount of water available per person will drop. Since 1970, the world's population has increased by over 2 billion and global water use has more than tripled. Many parts of the world are now experiencing rising water costs, poor water quality and inadequate water supply.

Strategy:

Practise conservation and use water efficiently.

3.6.1 Water Conservation Design

- 1. *Maintain native plantings and minimize high-maintenance landscapes, i.e., lawns.*
- 2. *Reduce overall water use to reduce wastewater production. Use water-efficient fixtures and appliances, i.e., low-flow shower heads and other flow restrictors.*
- 3. *Use greywater systems for non-potable uses, such as toilet flushing, laundry and irrigation.*
- 4. *Treat blackwater with on-site treatment systems.*
 - a. *Consider biological systems such as constructed wetlands.*

- b. Consider sand filters and aerobic tank treatment systems.*
 - c. Consider composting toilets.*
 - d. Consider aquaculture systems.*
- 5. Reclaim water from wastewater effluent for non-potable uses.*
 - 6. Treat wastewater on site and apply reclaimed effluent to the land.*

3.7. Indoor Air Quality

Indoor air quality is a core value of healthy housing principles and merits careful attention by the designer and home builder. Unhealthy indoor air quality is the result of outdoor and indoor sources of gaseous and particulate air pollutants that exceed the building's capacity to filter and ventilate the air to an acceptable level. Although many pollutants originate outdoors or from occupant activity, other pollutants are generated from the materials and furnishings used in buildings. Because of the high degree of energy efficiency achieved in the design of a building envelope, the natural exchange of air within the home is not frequent enough to remove potential pollutants. These material-based pollutants affect not only the performance of the materials comprising the envelope but also the health and productivity of the building's occupants.

Strategy:

Select building materials that minimize the exposure of building occupants to emissions from building materials and products.

3.7.1 Air Quality Design

- 1. Consider emission levels from building materials by reviewing manufacturer's Material Safety Data Sheets (MSDS) for materials with associated health risks.*
- 2. Consider the sink effect. Rough and porous surface materials with microscopic cavities may absorb airborne pollutants.*
- 3. Moisture and heat in materials increase emissions of pollutants and support microbial growth.*

3.7.2 Air Handling

The design of a healthy house must ensure that indoor air quality is maintained .If the appropriate air exchange cannot be achieved by passive flows, mechanical ventilation systems must be incorporated into the design.

4. Resources

Many resources are available on topics relevant to healthy housing, and a selection of such resources are listed here. These include readings on topics of sustainability; materials databases; assessment tools; checklists; energy efficiency and equipment guides; sustainable and community development; and funding resources. The resources are organized under three main headings: Sustainability and Socioeconomics; Electronic Guides and Databases; and Printed Guides and Databases.

4.1. Sustainability and Socioeconomics

Selected Readings on the State of Ecological Sustainability and Socioeconomics

Brown, L. et al. *State of the World 2001*. (New York, NY: Worldwatch Institute, W. W. Norton and Co., 2001).

Daly, H. and J. Cobb. *For the Common Good: Redirecting Economics towards Community, Environment and a Sustainable Future*, 2nd ed. (Boston, MA: Beacon Press, 1994).

Korten, D. C. *When Corporations Rule the World* (West Hartford, CT: Kumarian Press, 1995). (Look for an updated version due out in Spring 2001.)

Mander, J. and E. Goldsmith, eds. *The Case Against the Global Economy and For a Turn Toward the Local: 42 Essays by Ralph Nader, Vandanna Shiva, William Greider, Maude Barlow and Others* (San Francisco, CA: Sierra Club Books, 1996).

Myers, N. and J. Kent. *Perverse Subsidies: Tax Dollars Undercutting our Economies and Environments Alike* (Winnipeg, MB: International Institute for Sustainable Development, 1999).

Norberg-Hodge, H. *Ancient Futures: Learning from Ladakh* (San Francisco, CA: Sierra Club Books, 1991).

Sachs, W. *Planet Dialectics: Explorations in Environment and Development* (New York NY: St. Martin's Press, Inc., 2000).

Shiva, V. *Stolen Harvest: The Hijacking of the Global Food Supply*. (Cambridge MA: South End Press, 1999).

Wackernagel, M. and W. E. Rees. *Our Ecological Footprint* (Gabriola Island BC: New Society Publishers, 1995).

Grady, Wayne. *Green Home* (Buffalo, New York, Camden House, 1993).

4.2. Electronic Guides and Databases

A range of resources are available electronically, either via the World Wide Web or CD-ROM. The section on Interactive Guides includes environmental performance databases, guidelines for green building, listings of additional resources, environmental assessment and auditing tools, and feasibility tools for analyzing alternative energy sources for a particular location. The Web sites in the next section, Materials Databases, list environmental building products as well as other sustainable building guides and resources. The Web sites listed under the third section, Web Resources, provide a range of information such as lists of publications, examples of successful projects, an advisory system, and descriptions of embodied energy and LCA.

4.2.1 Interactive Guides

1. *ATHENA™ Beta 1.2* is an environmental assessment tool for the building design and research communities being developed by the ATHENA™ Sustainable Materials Institute. Designers can use Athena to look at the life cycle environmental effects of a complete structure or of individual assemblies and can experiment with alternative designs and different material mixes to arrive at the best environmental footprint. ATHENA™ allows comparisons of conceptual building designs in a holistic, life cycle framework. This limited function Beta version includes vertical and horizontal structural assemblies using wood, steel and concrete products. The model data sets encompass typical assemblies, standard structural products and existing typical technologies for producing products. This model is available free from the Web at <http://www.athenasmi.ca/>
2. The *BEES (Building for Environmental and Economic Sustainability)* balances the environmental and economic performance of building products. Aimed at designers, builders and product manufacturers, it

includes actual environmental and economic performance data for 65 building products. BEES measures the environmental performance of building products by using the environmental life-cycle assessment approach specified in ISO 14000 standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal. Environmental and economic performance are combined into an overall performance measure using the ASTM standard for Multi-Attribute Decision Analysis. For the entire BEES analysis, building products are defined and classified according to the ASTM standard classification for building elements known as UNIFORMAT II. This resource is available free from the Web at <http://www.bfrl.nist.gov/oae/software/bees.html>

3. *Designing for Low-energy Buildings – 10* by Sustainable Buildings Industry Council. CD-ROM. \$250.00 US.
Guidelines for Home Building. \$100.00 US.
 Both available from: www.sbicouncil.org
4. *Environmental Knowledge Base (EnvKB)*. Funded by US Army Corps of Engineer's Construction Engineering Laboratories and the US E.P.A. Available from: Design Harmony, 16N Boylan Ave. Raleigh, N.C. 27603. Phone: 919-755-0300. This extensive database/design tool offers environmental considerations at every phase of design, gives material suggestions and offers case studies. The program interfaces with MCASES cost estimating spread sheets, DOE 2.1, EXPOSURE, and includes the CERL Design Process Map and an alternative materials database. <http://www.shai.com/projects/envkb.htm>
5. *Green Building Advisor*, a CD-ROM which includes full text of Sustainable Building Technical Manual, by E-Build, Inc., copyright 1998, applicable to US including Alaska, \$170.00 US, phone 1-800-861-0954 or www.greenbuildingadvisor.com
6. *Green Building Information Centre* <http://greenbuilding.ca/index-fl.htm> lists additional interactive and auditing software, including information on the C-2000 program, the Easy Whole House Energy Audit, GBTool v.2, Green Building Advisor and others.
7. *Guide to Resource Efficient Building Elements*, 5th ed. Available from: Center for Resourceful Building Technology, P.O. Box 100, Missoula, MT

59806. Phone: 406-549-7678. Fax: 406-549-4100. Contains contact and product information for resource-efficient and recycled material manufacturers, producing everything from foundations to roofing. \$28.00 US. <http://www.crbt.org:81/pub.html>

8. *Retscreen*. Retscreen models provide feasibility study capabilities to analyze wind, solar, heat pump and other capabilities for a particular location. Databases for models are available at http://retscreen.gc.ca/ang/d_data_w.html
These databases provide daily, monthly and/or annual average values used to run the RETScreen models, including:
 - Horizontal solar radiation;
 - Wind speed;
 - Atmospheric pressure;
 - Relative humidity;
 - Ambient temperature;
 - Heating degree-days;
 - Heating design temperature;
 - Cooling design temperature;
 - Summer daily temperature range;
 - Frost days;
 - Earth (skin) temperature; and
 - Annual earth (skin) temperature amplitude.

In addition, hydrology data for more than 500 Canadian river gauges are available from the RETScreen International Online Weather Database for small hydro projects, and include:

- Flow-duration curves;
- Drainage area;
- Mean flow;
- Specific run-off;
- Canadian Regional Flow-Duration Curves (Map); and
- Canadian Specific Run-Off Map.

4.2.2 Materials Databases

GreenSpec: The Environmental Building News Product Directory and Guideline Specifications. Reviews more than 1200 green building products, in more than 200 categories. Also, see GreenSpec online listing of about 100 suppliers and categories of products www.GreenSpec.com Phone: 1-802-257-7300.

Jade Mountain. Lists green building supplies. Very comprehensive.
<http://www.jademountain.com/>

Oikos, by Iris Communications. Search online REDI Guide (Resources for Environmental Design Index) database of 1900 building materials. Very current. <http://oikos.com/index.lasso>

University of Berkeley California Library Web site. Several other green building material databases are listed at
<http://www.lib.berkeley.edu/ENVI/GreenAll.html>

University of Michigan Center for Sustainable Systems. Includes sustainable design, sustainable building materials, recycle/reuse guide.
<http://css.snre.umich.edu>

4.2.3 Web Resources

The Center for Resourceful Building Technology lists a number of useful publications dealing with resource efficiency, waste reduction and indigenous building materials. <http://www.crbt.org:81/pub.html>

Center of Excellence for Sustainable Development, by US DOE, provides many examples of successful projects, including some Canadian ones, and many site links. <http://www.sustainable.doe.gov/buildings/gbintro.shtml>

The Clean Process Advisory System (CPAS™) is conceived as a system of software for efficiently delivering information on clean technologies and pollution prevention methodologies to the conceptual process and product designer on an as-needed basis. The system is meant to address the challenge of incorporating environmental considerations into conceptual process and product design, where the majority of the waste can be reduced in a cost effective manner. Development of the system is occurring through a series of independent projects. <http://cpas.mtu.edu/>

Conservation Economy. www.conservationeconomy.net A description of all aspects of human enterprise, including housing, from the viewpoint of sustainability.

CSIRO Built Environment (Australia) - Online Brochures - Embodied Energy.
<http://www.dbce.csiro.au/ind-serv/brochures/3dcad/3dcad.htm>

Sustainable Architecture in Building Materials: Embodied Energy and LCA.
<http://www.sustainableabc.com/lca.html>

4.3. Printed Guides and Databases

4.3.1 Material and Design

AIA Environmental Resource Guide. This comprehensive guide has recently been updated and is a good text for sustainable design as well as how to make material selections. Available from: AIA Order Dept., 9 Jay Gould Court, PO Box 753 Waldorf, MD 20604. Phone: 1-800-365-ARCH. Fax: 1-800-678-7102.

Building Materials for the Environmentally Hypersensitive. This is a 238-page assessment of materials suitable for occupants with chemical sensitivities. Available from: CMHC Publications, PO Box 3077, Markham, Ontario L3R 6G4. Phone: 1-800-668-CMHC.

Environmental Choice M Program Certified Products and Services. This resource lists manufacturers and products which comply with Environment Canada's Ecologo requirements. Available from: Lynne Patenaude, TerraChoice Environmental Services. Phone: 613-952-0264.

Greenspec (Montpelier VT: Capital City Press, 2000). Binder and directory of 1200 green building materials. Phone: 1-802-257-0954. \$79.00 US.

Healthier Indoor Environments: Canadian Sources of Residential Products and Services. This directory includes a section on "Low Polluting Building Products, Materials, and Technologies," and also lists consultants who provide screening evaluations of materials and cleaning and maintenance products. Available from: Canadian Housing Information Centre, CMHC. Phone: 613-748-2367. Fax: 613-748-2098.

Indigenous Building Materials: An Overview. A booklet discussing methods, historical uses and current and potential applications for a number of resource-efficient indigenous building materials in North America, including adobe, strawbale, cob, cordwood, and rammed earth. \$8.00 US.
<http://www.crbt.org:81/pub.html>

Leclair, K. and D. Rousseau, *Environmental by Design, Professional Edition.* Available from: P.O. Box 95016, S. Van C.S.C. Vancouver, BC V6P 6V4.

Mendler, S. *The HOK Guidebook to Sustainable Design*. (New York NY: John Wiley & Sons, 2000). \$104.95. Phone: 1-800-567-4797.

R-2000 Procurement List. This list assists builders in selecting products which will meet R-2000 IAQ requirements, including carpet and padding, resilient flooring, paints and finishes, adhesives and composite wood products. Available through: John Broniek, Canadian Home Builder's Association. Phone: 613-230-3060.

Resourceful Specifications (choosing green building materials and techniques). Disk and binder \$35.00 plus \$5.00 shipping US. (Disk only \$20.00 + \$2.00.) Phone: 510-547-8092.

Speigel, R. and Dru Meadows, *Green Building Materials: A Guide to Product Selection and Specification* (New York NY: John Wiley & Sons, 1999). \$97.50. 1-800-567-4797.

SBIC, *Guidelines for Home Building*. For solar home design. Guide plus software \$100.00. Available from: SBIC, 1331 H Street, N.W., Suite 1000, Washington, DC 20005. Phone: 202-628-7400. Fax: 202-393-5043.

4.3.2 Community Development

Affordable Housing Solutions: Fifteen Successful Projects (Ottawa, ON: CMHC-SCHL, 1999).

Canadian Housing Statistics (Ottawa, ON: CMHC-SCHL, 1999).

Community Energy Management foundation paper (Ottawa, ON: CMHC-SCHL, 2000).

Conventional and Alternative Development Patterns (Ottawa, ON: CMHC-SCHL, 1997).

Levies, Fees, Charges, Taxes and Transaction Costs on New Housing (Ottawa, ON: CMHC-SCHL, 1997).

The Long Term Housing Outlook, 1991 – 2016 (Ottawa, ON: CMHC-SCHL, 1997).

Planning Study of Native Northern Communities (Ottawa, ON: CMHC-SCHL, 1997).

Regulatory Obstacles to Innovative Housing (Ottawa, ON: CMHC-SCHL, 1998).

Sustainable Residential Developments, Planning, Design and Construction Principles (Ottawa, ON: CMHC-SCHL, 1993).

4.3.3 Checklists

The Basics of Resource-Efficient Building.

<http://www.ecoetc.com/sshelter/REBldg.htm>

“Building Materials: What Makes a Product Green?” in *Environmental Building News* 9:1 (January, 2000).

“Checklist for Environmentally Responsible Design and Construction” in *Environmental Building News*. Available at <http://www.buildinggreen.com/ebn/checklist.html>

“Establishing Priorities with Green Building” in *Environmental Building News* 4:5 (Sept./Oct. 1995).

WYKO, IYSO Test, “Would you know one if you saw one? A visioning and Assessment Exercise for Sustainable Communities” in *CMHC Sustainable Communities* (Ottawa, ON: Canada Mortgage and Housing Corporation).

4.3.4 Energy and Equipment

A Guide to Mechanical Equipment for Healthy House Environments research report. (Ottawa, ON: CMHC-SCHL, 2000).

Water Quality Guideline and Water Monitoring Tools for Residential Water Reuse Systems research report (Ottawa, ON: CMHC-SCHL, 2000).

Analysis of Utility Costs in Public Housing (Yellowknife, NT: Northwest Territories Housing Corporation, 1997).

On-Site Waste Water Recycling: Phase 1 and 2 (Yellowknife, NT: City of Yellowknife, March 2000).

Kadulski, Richard. *Heating Systems for your New Home* (North Vancouver BC: The Drawing-Room Graphics Services Ltd., 1998).

McKirdy, Alexandra R., ed. *The Canadian Renewable Energy Guide*, 2nd edition (Solar Energy Society of Canada, 1999).

Photovoltaic Systems Design Manual. (CANMET, Energy, Mines and Resources Canada, 1991).

Stand-Alone Wind Energy Systems: A Buyer's Guide (Ottawa, ON: Natural Resources Canada, 2000).

Swartman, Robert, ed. *(CSIA) Manual on the Installation of Solar Domestic Hot Water Systems* (The Canadian Solar Industries Association, 1991).

Wind Energy: Basic Information and Small Wind Energy Systems Technical Seminar (Ottawa, ON: Natural Resources Canada, CANMET, 1996).

Tap The Sun, Passive Solar Techniques and Home Designs (Ottawa, ON: CMHC-SCHL, 1998).

4.3.5 Funding

Action Plan 2000 on Climate Change (Ottawa, ON: Government of Canada, 2000.)

Federation of Canadian Municipalities, *Green Municipal Enabling Fund*

Natural Resources Canada, *REDI Program*. Available at:
[HTTP://WWW.FCM.CA/PCP/GMEF/CRIT-E.HTML](http://www.fcm.ca/PCP/GMEF/CRIT-E.HTML)

Northern Ecosystem Initiative (NEI) (Ottawa, ON: Environment Canada, 2001). Available at:
[HTTP://WWW.NRCAN.GC.CA/ES/ERB/REED/BACKG_E.HTM](http://www.nrcan.gc.ca/es/erb/reed/backg_e.htm)

Visit our home page at www.cmhc-schl.gc.ca