SUSTAINABLE HOUSING
FOR A COLD CLIMATE

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for

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INTRODUCTION

Concern over the global environment has been growing steadily in recent years, particularly since the release of the 1987 report by the World Commission on Environment and Development. Cold climate countries, such as Canada, contribute disproportionately to environmental stresses because of higher per capita consumption of energy, water and other resources, and higher generation of related air, water and soil pollutants.

Canada Mortgage and Housing Corporation (CMHC), the federal government's housing agency, has undertaken a serious examination during the past two years of how Canadian housing can be made more sustainable. Housing is an important component of the sustainable development equation, having significant impacts both environmentally and economically.

While the term "cold climate housing" conjures up images of Canada's far north, this paper will focus on the more temperate regions of Canada where the majority of the Canadian population lives. This paper summarizes the relation of cold climate housing to the environmental crisis, proposes a broader definition of sustainability with respect to Canadian housing, and describes the implications this will likely have for housing designers and builders.

I. ENVIRONMENTAL AND ECONOMIC IMPACTS

1. The Environmental Crisis Versus the Energy Crisis of the 1970s

It is important to emphasize the differences between the current environmental crisis and the energy crisis of the 1970s. Fifteen years ago, the primary concern was saving energy in order to save money and to be less dependent on foreign supply. Today, Canadians are faced with a vast range of environmental impacts, many of which are global in nature, and some of which demand major societal changes.

The report of the World Commission on Environment and Development stressed the need to consider environmental and economic issues together, and gave many examples of their complex interrelationships (1). Other agencies, such as CMHC and Health and Welfare Canada, have added a third dimension: health and social aspects.

It is therefore necessary to take a very broad approach to the issue of sustainable development. This is particularly true for housing, which affects the environment in a variety of ways and which plays a vital role in the Canadian economy and in Canadian society.

2. Impact of Housing on the Environment

The production and operation of residential developments in Canada have a significant impact on the environment. The following summarizes the scope of such impacts (2).

Energy: Cold climate countries are generally high energy consumers, due to space heating requirements and transportation costs. Canada's total energy usage is one of the highest per capita in the world. It should be noted that our energy usage is 50% higher than countries such as Sweden, which have similar climates and sparse populations. Therefore, at least some of this consumption is attributable to non-sustainable aspects of our lifestyle. Such energy usage relates directly to environmental issues such as greenhouse gas emissions, acid rain, the flooding of aboriginal lands and the disposal of radioactive waste. Approximately 20% of our total energy consumption is for the heating, cooling and operating of housing. In addition, the indirect or embodied energy from the construction, renovation and demolition of housing and its associated infrastructure may account for an additional 5-10% of total energy usage.

Water/Wastewater: While water supply is not generally a problem in cold countries, the cost of water treatment, wastewater disposal and the associated infrastructure has become a major issue. Canadians rank second after the US in water consumption per person, which is 80% more than in Sweden. Of domestic water use, only 5% is used for the essentials of drinking and cooking, while 70% is used for flushing toilets and watering lawns. Only 44% of Canadian communities are served by some form of sewage treatment.

Solid Waste: In spite of being second largest country in the world, Canada faces a serious landfill crisis, since most of our population is concentrated in a small number of urban centres. Related to this crisis is the growing problem of toxic lands, resulting in contaminated soils and groundwater. Canadians produce on average 2 kg of solid waste per person per day, the highest in the world. Construction is responsible for 16%, of which approximately one fifth is from new homes. A typical new house in Toronto creates 2.5 tonnes of construction waste.

Land Use: Agricultural land can be quite limited in cold climate countries, due to short growing seasons. Approximately 50% of the best quality agricultural land in Canada is within 160 km of major urban centres and may eventually be threatened. Residential developments typically consume 50% of urban land, while their road patterns consume another 20%. Single family detached dwellings, the least efficient form of housing, shelters 60% of Canadians. Sprawl has meant that transportation has now overtaken space heating and industrial activities as the most significant source of air pollution in cities. Low density housing, combined with the resulting dependency on private automobiles for transportation, represents perhaps the greatest challenge to urban sustainability in Canada, due the multiple impacts on energy use, infrastructure, air pollution and agricultural lands.

3. Impact of the Environment on Housing and Its Occupants

Housing, in addition to causing environmental problems, can also suffer the consequences of such problems.

Housing is particularly vulnerable to the infiltration of **soil gases**, such as methane and other volatile organic compounds from landfills and contaminated sites. This becomes problematic for urban intensification and redevelopment.

Indoor air pollution can be a problem in cold climate housing, since we spend so much of our time indoors, and since our housing is becoming increasingly well sealed and increasingly built and furnished with synthetic materials. Poorly conceived or implemented energy conservation measures can compound the problem. Exposure to indoor air pollutants can lead to health and allergy problems, and in extreme cases to hypersensitivities.

Our **dependency on the electrical grid** leads to vulnerability during times of brownouts and power failures, particularly for populations such as the elderly.

As a consequence of the requirement for frost-protected foundations to prevent structural movement, the majority of Canadian housing has included basements, which have been used increasingly as habitable space. However, poorly managed **storm water runoff** has proven to be a major factor in causing basement flooding (3), resulting not only in property damage, but in occupant health problems from the associated mould growth.

More serious environmental impacts on housing could lie ahead, when one considers the effects of **climate change** from global warming. Stronger and more frequent winds and storms will take their toll on building durability. More frightening is the potential devastation of Canadian coastal cities from rising sea levels.

4. Housing and the Economy

Since Canada is a young, sparsely populated, growing country, housing plays a particularly vital role in the economy, representing one million person-years of employment per year and 5% of our gross domestic product. Residential mortgages represent 25% of all debt in Canada, while homeownership is the largest single source of equity for most Canadians.

Housing activity is a weathervane for the national economy. A change in housing starts is regarded as one of the first confirmations of a boom or recession. The state of the economy can have windfall or calamitous effects on resale values.

To date, environmental problems have not had a major impact on housing values, with the exception of properties affected by contaminated soils or by periodic flooding. However, if the true environmental costs were factored into energy and resource prices, what would be the impact on the cost of owning and operating a house, and how would this impact the Canadian economy?

5. Unique Challenges Associated With Canadian Housing

The role and nature of housing in North America creates additional societal and logistic challenges to improved sustainability.

Variability and Regionality: Housing is less standardized than office or commercial space, with great variability in terms of design, size, age, method of construction, quality of workmanship, and range of mechanical equipment. The diversity of the Canadian climate, ranging from 3,000 to 13,000 Celsius degree days, is an additional complicating factor. Regional building practices have evolved in response to climate, to the local availability of materials and energy sources, and also to historical traditions and socio-cultural values. It is not possible to take a consultant's approach to each house, yet it is difficult to prescribe generic solutions. For example, airtightening may make some houses more energy efficient, while creating air quality problems in others.

Fragmented Nature of the Housing Industry: The design and production of housing in Canada is highly decentralized, involving a large number of small contractors. More than 70% of builders, for example, build five or fewer units per year. The housing industry is generally conservative and demand-driven, with innovations taking root quite slowly. The provision of adequate training and education for such an industry is difficult.

Ownership and Control: The ownership of housing is also highly decentralized, with 62% of Canadian housing being owner-occupied. The furnishing, maintenance and operation depends primarily upon the occupants, whether owners or tenants. Educating such a large and diverse population about energy and environmental issues poses a great challenge.

Role as an Investment Vehicle: Housing has become an expensive commodity in Canada, due partially to the requirements of a severe climate, but primarily as a result of general affluence and of high land costs from urbanization pressures. Housing has therefore become the single largest expenditure and single largest investment for most Canadians (4). As our mobility has increased, so has our fixation on resale value. This has two implications for sustainability: homeowners may be unwilling to undertake "green" capital improvements when current interest rates make payback periods excessively long, and the "not-in-my-backyard" (NIMBY) syndrome may be a major obstacle to urban intensification.

II. TOWARD A BROADER DEFINITION OF SUSTAINABILITY

While energy continues to be a dominant theme in northern industrialized countries, the concept of sustainability extends to all aspects of the environment, and must also address economic and social issues. Sustainable housing, in CMHC's view, must respond successfully to a broad range of criteria. These include the following:

1. Energy and Resource Aspects

These factors are perhaps the most obvious and immediate in terms of environmental impacts.

Reductions in total operating energy are required primarily to reduce greenhouse gas emissions. Building on the experience of the R2000 Program developed by Energy Mines and Resources Canada and the Canadian Home Builders' Association, such reductions should incorporate energy-efficient appliances, mechanical systems and building envelopes.

Reductions in peak energy loads are necessary to avoid major expansions of energy generation facilities and minimize the usage of present fuel-fired back-up electrical generation. Ideally, housing should be as energy-autonomous as possible.

Maximum use of renewable energy will assist in reducing both total and peak energy, and may include greater use of passive solar space heating, active solar water heating, photovoltaics, and ground source heat pumps.

Reductions in material usage and embodied (indirect) energy should demonstrate the maximum use of recycled, recyclable and renewable materials, and the selection of materials and products which are less energy intensive in their manufacture.

Reductions in water consumption and wastewater production should ease the burden on sewage treatment facilities and make efficient use of dwindling fresh water supplies.

Reductions in solid waste, both during the construction phase and during the lifetime of the building, are essential to postpone the looming landfill crisis and associated soil contamination.

2. Building Science Aspects

The energy crisis of the 1970s gave Canadians a chance to make mistakes. There is now an opportunity to apply the lessons in building science which have been learned by those mistakes. The aftermath of the energy crisis brought much research into moisture, air quality and ventilation problems. New ground was broken in understanding the fundamentals of heat, moisture, air and energy flows. Canadian researchers developed a solid understanding of the inter-relatedness of building components - the "house as a system" approach (copyright by Target Communications Ltd). We can now be more confident in recommending energy efficient changes to new and existing construction without fear of affecting the durability of the building or the health of its occupants.

A systems approach is required to address energy and environmental concerns in a manner which considers the inter-relatedness of the house components, and which does not create undesired side effects.

Healthy indoor environments must be created through good indoor air quality and occupant hygrothermal (temperature and humidity) comfort.

Durability of the building envelope, particularly with respect to moisture deterioration, must be considered when undertaking changes in energy and material usage, in order to ensure the longevity of the housing stock.

3. Affordability Aspects

In CMHC's view, affordability is also an integral part of sustainable housing. Sustainability must be shown to be within the reach of typical Canadians, and must not place great strains on public budgets, nor create further cycles of dependence.

Optimum use of building sites and interior spaces should be a design objective.

Adaptability to changing tenures is needed to facilitate family changes, aging in place and accessory apartments.

Expandability should facilitate a gradual increase in finished space as families grow and as the space can be afforded.

Self-help can reduce capital, debt service and maintenance costs for owners.

4. Commercialization Aspects

The greening of the Canadian housing industry will not become a reality unless such changes can be seen to be economically feasible.

Market potentials must exist, if the private sector is to become fully involved and if innovative designs, materials and technologies are eventually to succeed commercially.

Trade potential should be created overseas from advances in the Canadian manufacturing, construction and consulting industries.

Applicability to the existing stock is essential, in that new housing represents only a small fraction of the total stock (currently less than 2% per year).

5) Community Aspects

The above criteria may lead to a sustainable house, but not necessarily to sustainable housing. While it is beyond the scope of this paper to examine community planning issues, it is important to acknowledge that major changes are required at this level.

The Toronto protocol target of a 20% reduction in carbon dioxide emissions by the year 2005 will really mean a reduction of 50%, considering that growth in energy usage over the next 15 years is expected to be 60%, and therefore the target reduction should be thought of as being from 160% to

80% of current consumption. Furthermore, the 20% target itself was considered a compromise between what was felt to be realistically attainable, and what is needed, which is a 50-80% reduction according to climate change experts (5). A reduction of this magnitude can not be achieved simply by addressing individual buildings; the entire pattern of community energy use must be examined.

There is increasing discussion on criteria for more sustainable communities. Included are such factors as minimum encroachment on agricultural land and natural habitat, optimum use of existing infrastructure, and minimum transportation energy and related air pollution. Meeting these criteria will likely mean urban intensification, a reduced rate of suburban expansion, and better integration of housing with employment and services.

III. IMPLICATIONS FOR THE DESIGN AND CONSTRUCTION OF COLD CLIMATE HOUSING

The above criteria lead to design and construction implications at three levels: at the level of components - products, materials and equipment, at the level of the housing unit, and at the level of the neighbourhood and community.

The following is a discussion of current and recent research at CMHC and other agencies, with an emphasis on how research findings may change the way Canadian housing is designed and built.

1. Sustainable Components: Products, Materials and Equipment

a) Minimizing Embodied Energy

CMHC is nearing completion on a project entitled **Energy Intensity of Building Materials and Techniques**, which is examining the embodied or indirect energy associated with building materials. Such embodied energy includes the energy expended in the extraction of raw materials, primary processing, secondary manufacturing, component assembly, site construction and eventual demolition. This is a challenging task, since it is difficult to define the boundaries of what should be included and to obtain meaningful data on the range of activities involved. Some of the most energy intensive materials also present the greatest opportunities for recovery and recycling, which is a further complication (6).

In spite of these limitations, preliminary results are proving to be highly interesting. The embodied energy in a building appears to equal ten to thirty years of operational energy. This is quite significant, especially for housing, which often has a shorter life expectancy than commercial or institutional buildings. An examination of the embodied energy in typical residential assemblies can yield some surprises. For example, in a typical wood-frame wall, the dominant energy components are the interior paint and the gypsum board (7).

A study of embodied energy also allows a payback calculation which is based on the energy invested and the energy saved, or the "energy-return-on-investment". This offers a different perspective from conventional payback analyses, which are dependent on the fluctuating (and often policy-influenced) prices of energy, materials and labour. For example, in comparing a conventional glass fibre insulated 2x4 wood frame wall with a 2x6 wall, it can be seen that there will be additional embodied energy associated with the increase in framing material and insulation. This has been estimated to have an "energy payback" of approximately three years, which is quite favourable.

Another initial observation arising from this work is that Canadian wood frame construction is generally a low-energy technology, suggesting a bright future for this technology both domestically and abroad, as environmental issues become more important.

The result of CMHC's work in this area is a design tool in the form of a spreadsheet, which can be used by designers, builders and policy makers to assist them in making material selections.

b) Minimizing Indoor Pollutants

CMHC has initiated a supplementary materials project entitled **Building Materials Options**, which is further evaluating current and alternate building materials from two perspectives. In addition to examining the environmental impacts associated with material production, this project is ranking materials in terms of pollutant offgassing which may negatively affect indoor air quality. This latter perspective builds on the results of several earlier projects which sought to address the challenge of providing suitable housing for the chemically hypersensitive (8).

c) Adapting to New Technologies

The 1989 Buildings for the 21st Century Workshop (9) highlighted the emerging trends in innovative building materials and mechanical systems, many of which have the potential for reduced energy consumption and more benign environmental impact.

As emerging building technology is a vast subject, only a cursory treatment will be provided here by means of two contrasting examples.

The first is an example of a rapidly evolving area of component technology which will have broad implications for cold climate buildings: **advanced glazings**.

"Superwindows" have already made major inroads in the marketplace, particularly those windows involving low emissivity glazings and inert gas-filled units. Still under development are advancements such as switchable electrochromic glazings, silica aerogels and vacuum units (10).

Windows take on great significance in cold climate housing. On the one hand, they can be a source of solar gain, provide natural light and views, and help to alleviate the psychological effects of being cut off from the outdoors for half of the year. On the other hand, they are the single largest source of heat loss in most houses. Therefore, dramatic improvements in the thermal and transmission properties of glazing can have the potential to greatly improve the comfort and performance of cold climate housing. Advanced glazings will likely revolutionize the feasibility of passive, and probably active, solar systems. This will have major impacts on site design, interior layout, heat storage and distribution, the sizing of conventional heating systems and allowable humidity levels.

The second, for contrast, is an example of a less glamorous component technology where unfortunately very little work is being done at present: **ventilation fans.**

Adequate ventilation and good indoor air quality are particularly important issues in cold climate housing, since so much time is spent indoors for much of the year, and since the rigours of the climate demand airtight envelopes for minimal infiltration of outdoor air.

With the passing in 1990 of Canada's first residential ventilation standard, CSA F326, it has been a rude shock to discover that typical residential exhaust fans available to builders have energy efficiencies in the order of 3%! (11) Furnace blowers have average efficiencies of only 10%. By comparison, air moving equipment in commercial buildings is typically 50-60% efficient. Worse, most residential fans have life expectancies of less than 6 months, if used continuously. Such poorly performing equipment has negative impacts on both energy efficiency and indoor air quality. Clearly, it is pointless to be prescribing sophisticated ventilation and heating systems until the performance of the basic components of such systems can be improved.

d) Coordinating/Integrating Building Components

In addressing both global and indoor environmental issues, designers and builders will need to develop a greater familiarity with an increasingly vast array of materials and equipment. In addition, they will need to ensure that innovative and traditional products perform well together and perform acceptably under specific real-world climatic and jobsite conditions.

This coordinating and integrating role will require an increased and almost "intuitive" knowledge of building science, backed up by improved access to more sophisticated research data and computer modelling, as appropriate.

2. Sustainable Houses

Canada has already demonstrated international leadership in residential energy efficiency through the development of the R2000 Program by Energy Mines and Resources Canada (EMR) and the Canadian Home Builders' Association (CHBA). The following outlines some of the initiatives at CMHC and other agencies which aim at furthering Canada's ability to build low-energy, environmentally sound housing.

a) Reducing Operating Energy

A joint venture with EMR, entitled **Environmental Impact Study for Housing: CO_2 Emissions** is assembling a data base of energy usage patterns for typical Canadian housing, based on age and geographic distribution. This will then be used to undertake technology assessments in order to predict the relative effectiveness of various residential energy efficiency strategies at reducing greenhouse gas emissions, such as envelope improvements, appliance improvements, heat pumps, integrated appliances, and cogeneration systems.

One area of particular interest to CMHC is that of integrated mechanical systems. A project on the **Rationalization of Residential Energy Systems** is examining opportunities for a more integrated approach to the use of energy in the home. Possibilities include the downsizing of mechanical systems to reflect improved envelope and appliance efficiencies; methods of integrating heating, cooling, ventilation, food storage/preparation, lighting and other energy needs; and innovative methods of incorporating waste heat recovery from exhaust air or greywater.

In terms of renewable energy, much valuable work has been undertaken at EMR on the use of passive solar energy and at the National Research Council (NRC) on improved ground source heat pumps. The greater use of sunspaces and atria will likely become a more important feature of building design because of the heating, lighting and psychological/health benefits. However, proper design and detailing are vital with respect to orientation, thermal storage, heat distribution, insulation and summer ventilation, in order to ensure that such spaces do not become merely another "feature" which overheats in summer and loses energy in winter. CMHC's contribution has been to recognize that detailed calculations and computer simulations represent an obstacle for most designers. CMHC has therefore developed graphic tools, such as "GRAPHEAT" (12) and "GRAPHSHADE" (13), and has published rules of thumb (14) in order to assist designers in successfully incorporating passive solar into conventional housing.

The ultimate goal of energy efficiency would be a zero-energy house. A proposed project to be initiated in 1991 will look at the theoretical limits to energy efficiency and the use of renewable energy at the scale of a housing unit, in order to better target future research.

It should be noted that despite all the energy-related research which has been undertaken, there are still surprises. For example, some studies have indicated that energy consumption per area in high rise apartments can be similar to detached dwellings, despite having a much more efficient ratio of exterior surface to interior volume. High rise apartments therefore represent fertile ground for energy improvements.

b) Reducing Other Environmental Impacts

In water and wastewater, a project on **Residential Water Conservation** is documenting, with Environment Canada, the various technologies and strategies available to allow reductions in water consumption and wastewater production in housing. In addition to newly available options for builders and designers such as flow restrictive and aerated faucets, low-flush toilets and more sophisticated flow controls, this project is assessing the feasibility of two-pipe systems for separating potable and non-potable water, and the use of rainwater capture and retention.

In the reduction of solid waste, CMHC is collaborating with the Toronto Home Builders' Association (THBA) on a project entitled **Demonstration of Alternative Waste Management Techniques in Residential Construction**. Stimulated by THBA's report on the current landfill crisis (15), this project is analyzing the factors affecting the generation of on-site construction waste in both new housing and renovation activities, investigating recycling opportunities (it is believed that as much as 50% of current waste can be re-used) and demonstrating various solutions. A similar project is commencing with the Canadian Home Builders' Association of British Columbia. For designers, "optimum value engineering" design practices (16) can result in modular layouts and optimum spans, reducing both overall material usage and the amount of construction waste.

c) Incorporating Building Science Solutions

In the realm of building science, CMHC, EMR, NRC and other research agencies have developed an improved understanding, throughout the 1980s, of the complex and often subtle relationships which exist among the building envelope, mechanical systems, weather conditions, soil conditions and building occupants, and the resulting impacts on heat, air and moisture flows. This systems approach to housing research has focussed on the avoidance of moisture and indoor air quality problems in cold climate buildings.

In moisture research, it is now realized that earlier energy conservation measures often brought building envelopes to their limits of "forgiveness", resulting in problems which had implications both for building durability (moisture-related deterioration) and for occupant health (moulds and respiratory disease). Research has highlighted the necessity for internal moisture source control; for improved envelope detailing, particularly with regard to air barriers and the compartmentalization of rainscreens; for intelligent ventilation systems which remove rather than add to moisture accumulation in cavities, crawl spaces and attics; for the modelling of innovative assemblies to assess performance under different climatic conditions; and for a regionally sensitive application of building codes (17).

Indoor air quality research has highlighted the necessity for appropriate selection of low-offgassing materials; for the proper design of combustion systems to prevent the spillage of combustion products in to the interior air; for the installation of effective ventilation systems to control carbon dioxide and various pollutants; and for creating barriers or vent systems to minimize the infiltration of radon and other soil gases into basements.

d) Improving Affordability

In terms of affordability, initiatives in modest designs, such as the Lebreton Flats narrow-front townhouses of the late 1970s or the more recent "Grow Home" at McGill University contain many lessons for designers and builders. It should be noted that while Scandinavian houses have been decreasing in size throughout the 1980s, Canadian homes have been increasing. Clearly, designers will need to create innovative and multi-use interior space in order to "sell" modesty.

CMHC has pioneered the concept of flexible **Made-to-Convert Housing** (18) which can adapt to changing tenures, allowing separate apartments to be created and later rejoined, as demonstrated in 1989 with the Canadian Home Builders' Association (CHBA) and the Hamilton District Home Builders' Association in the "Charlie House".

The issue of expandability to allow families to increase their living space incrementally as they can afford it has been addressed through two projects which looked at expansion within the building shell.

Reclaiming the Attic (19) proposes a return to habitable attics, combining a traditional idea with new framing technologies. Various truss configurations were found to provide opportunities for future low-cost habitable space.

Another project, **Advances in Basement Technology** (20), prescribes methods of achieving higher performance basement construction for additional high quality living space which is free from moisture and soil gas problems. This project also proposes simplified construction practices, reducing the number of "layers" in basement construction from 8 to 2, reducing greatly the number of person-trips around basements during construction, and thereby reducing overall costs.

The development of a **Life Cycle Costing Model**, complete with a detailed energy analysis module and a database of capital, maintenance, operating and replacement costs, is currently at the trial usage stage, and will provide a valuable design tool for determining optimum strategies for lowering long term housing costs. Many designers already are using computer tools such as the HOT2000 program to estimate the energy performance of alternatives.

In self-help, CMHC is completing a 5-year 500-unit **Rural and Native Demonstration Program**, which appears to have been quite successful in providing basic owner-built shelter in northern and remote areas for approximately $40-45K per unit. For designers, opportunities exist to develop designs and construction systems which have been simplified and rationalized to allow easy assembly. CMHC is also examining the possibilities for urban self-help activities, and is currently providing assistance to the pilot Whitney Pier project in Sydney, Nova Scotia, involving ten families. CMHC studies have found that self-built or self-contracted housing accounts for more than 25% of all units built in Canada annually, that the quality is equal to industry built units, and that such housing has a greater chance of being well-maintained (21). While industry often regards such activities as competing, it would appear that self-help actually generates work for sub-trades, adding to housing starts which could not be afforded otherwise (22).

3. Sustainable Neighbourhoods and Communities

As this paper focuses on buildings, it will not include a detailed summary of current urban planning issues, but can provide a thumbnail sketch of how probable changes in residential planning may affect the design and construction of housing.

The greatest change is likely to be a decreased reliance on private automobiles for transit. Reduced mobility will need to be balanced by higher densities and a greater mix of uses to allow housing to be closer to employment, schools and services. The "green" communities of the future, in addition to having more energy and water efficient buildings, may have the following characteristics: smaller lot sizes, reduced setbacks and road allowances; fewer cars per household and greater use of public transit, pedestrian walks and bicycle routes; minimum production of garbage and more integrated recycling programs; more ecological use of yards, with less lawns and more gardens and natural vegetation; greater retention of storm water; better use of infrastructure; more diverse populations and tenures; greater control of air and water pollution; and greater preservation of natural habitat and waterways (23).

Such changes will have numerous implications for designers and builders.

a) Intensifying Urban Areas

Innovative designs will be needed to make higher densities more acceptable, perhaps drawing heavily from Canadian experiments of the 1970s and from Scandinavian examples, which have used dwelling arrangements to define courtyards and create interesting and humanly-scaled urban spaces (24). Greater densities will mean designing for visual and acoustic privacy, both indoors and outdoors. The combination of higher densities and more modest dwelling sizes will place a greater premium on good design in order to achieve success in an increasingly competitive marketplace.

b) Designing for Climate

Apart from having increasingly energy efficient building envelopes and heating appliances, current Canadian housing is generally not designed for the rigours of the Canadian climate. House plans and site design often seem more reminiscent of winter vacation spots than of winter cities. Yet from the following comparison of winter severity indices (25), it can be seen that most Canadian cities are indeed "winter cities". Even Toronto has more severe winters than northern centres such as Oslo, Stockholm or Reykjavik.

Major Canadian Cities		Northern European Cities	
Saskatoon	55	Moscow	54
Quebec	54	Helsinki	48
Winnipeg	53	Oslo	42
Ottawa	50	Reykjavik	38
Edmonton	49	Stockholm	36
Montreal	49	Copenhagen	25
Calgary	44		
Toronto	43		

At the same time, it is also important to recognize that Canadian cities, especially those in continental areas, can suffer from periods of extreme heat in summers.

Therefore, neighbourhoods need to be designed to create favourable micro-climates for both extremes. Unit arrangements should minimize winter winds, control snow accumulation, and optimize solar orientation in winter, while taking advantage of summer shading and breezes, and minimizing solar penetration in summer. Better use needs to be made of indigenous trees and groundcovers. One source has claimed that a 40% reduction in heating and cooling loads is possible simply via site design and landscaping (26).

Such climate-responsive design is, of course, difficult to undertake once lot lines have been set, and therefore needs to be incorporated early into the planning process. Scandinavian countries appear to have made considerable progress in designing communities and buildings for solar penetration, wind deflection and snow scouring. Since the 1950s, Swedish building codes have specified minimum amounts of sunlight penetration into living rooms, kitchens and balconies (27).

c) Enhancing Existing Communities

Hopes for more sustainable housing cannot depend exclusively on the creation of new "green" communities or subdivisions. Environmental principles must also be gradually incorporated into the existing urban fabric. As such concepts are applied to existing communities, opportunities will arise for designers to develop innovative ways of increasing existing densities through infill housing, through the use of former rights-of-way, and through the use of lightweight structures to increase existing building heights (28).

d) Reforming the Regulatory Process and Influencing Consumer Attitudes

In terms of regulatory implications, there is a general consensus that regulatory reform will need to become another element of a sustainable approach to housing. An example is the **Affordability and Choice Today (ACT) Program** sponsored by CMHC, the Canadian Housing and Renewal Association (CHRA), the Canadian Home Builders' Association (CHBA) and the Federation of Canadian Municipalities (FCM). This program is demonstrating ways of streamlining the regulatory process to encourage innovative and optimum land use.

A challenge to innovative planning and design is the NIMBY syndrome. Concern over the environment can be used by neighbourhood groups as a reason for blocking higher density developments. This phenomenon underscores the necessity of consumer education. A CMHC project entitled **Consumer Housing Choices and the Environment** is developing a decision matrix for the many housing-related choices facing consumers and the associated impacts on energy usage and the environment, in order to assist consumers in understanding the impacts of their decisions and attitudes.

CONCLUSIONS

With such a broad and challenging range of concerns to be addressed, the issue of sustainable housing for cold climates requires a synthesis of effort at this point to provide integrated and holistic solutions.

Having put forward a vision of sustainable housing, having launched a number of projects to assemble the necessary "building blocks" of information, and having developed over a period of many years an expertise in the environmental, building science and societal aspects of Canadian housing, CMHC feels it is in a unique position to "put all the pieces together" and to demonstrate such an integrated approach.

CMHC has therefore proposed for 1991-92 a "Healthy Housing Design Competition to develop prototypical house designs which are "healthy" for both the occupants and the global environment. It is expected that details will be announced in the second quarter of 1991.

This program will only address the issue of the sustainable house; sustainable communities remains a much larger challenge for the years ahead.

For housing designers, the environmental crisis calls for a renewed commitment to the sensitive design of housing units, neighbourhoods and communities. Not only do designers need to stay abreast of current research and innovation, they may also need to become more involved in the delivery of housing; the future may see greater partnership of designers with developers or with community housing groups. While many may say that architects have abdicated their role in housing, the challenge of sustainable urban environments provides an open door for their return.

Visions of the future are a contrast of fantasy on the one hand - domed communities, underwater cities, advanced technology - and on the other hand the deteriorating reality of the homeless and the affordability crisis. The sustainable housing of tomorrow will need to encompass both visions.

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