

RESEARCH REPORT



Sustainable Housing: A Background Paper for the City of Montreal's Proposed Housing Design Competition



CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) has been Canada's national housing agency for more than 60 years.

Together with other housing stakeholders, we help ensure that Canada maintains one of the best housing systems in the world. We are committed to helping Canadians access a wide choice of quality, affordable homes, while making vibrant, healthy communities and cities a reality across the country.

For more information, visit our website at **www.cmhc.ca**

You can also reach us by phone at 1-800-668-2642
or by fax at 1-800-245-9274.

Outside Canada call 613-748-2003 or fax to 613-748-2016.

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.

SUSTAINABLE HOUSING

**BACKGROUND PAPER FOR
THE CITY OF MONTREAL'S
PROPOSED HOUSING
DESIGN COMPETITION**

April, 1991

SUSTAINABLE HOUSING

**A BACKGROUND PAPER FOR THE
CITY OF MONTREAL'S
PROPOSED HOUSING DESIGN COMPETITION**

Prepared for:

**Project Implementation Division
Canada Mortgage and Housing Corporation**

Prepared by:

Marbek Resource Consultants Ltd.

April 3rd, 1991

DISCLAIMER

The analysis, interpretations and recommendations of this report are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in this publication.

NOTE: Disponible en français sous le titre: Le Logement durable:
Document d'information pour le projet de concours de conception
de logements pour la ville de Montréal

TABLE OF CONTENTS

1.	INTRODUCTION	1
1.1.	Background	1
1.2	Purpose of and Approach to the Paper	1
1.3.	Impetus for Sustainable Housing	2
2.	POTENTIAL CLIENT GROUP AND ELEMENTS THAT MAY APPEAL TO THEM	4
2.1.	Probable Characteristics of Clientele for Sustainable Housing	4
2.2.	Elements of Potential Appeal to Early Adopters of Sustainable Housing	5
3.	GOALS FOR SUSTAINABLE URBAN HOUSING	7
3.1	Reduced Resource Consumption and Appropriate Resource Use	8
3.2	Reduced Environmental Impacts (Natural and Built Environments)	10
3.3	Improved Health and Well-Being	12
3.4	Affordability and Marketability	14
4.	REVIEW AND ANALYSIS OF APPROACHES TO MEETING THE GOALS OF SUSTAINABILITY	15
5.	CONCLUSIONS: IMPLICATIONS FOR THE COMPETITION	28



1. INTRODUCTION

1.1. Background

The City of Montreal, with support from other parties including the Canada Mortgage and Housing Corporation, is preparing a design competition for small-scale (six to eight unit) residential developments on four "insertion" sites in existing urban neighbourhoods. The City is thereby creating opportunities to explore a diversity of residential approaches within existing land constraints.

Given its moderate property prices compared to most major North American urban centres, Montreal presents a relatively affordable option for city living. Nonetheless, the two decades preceding the mid eighties saw a substantial exodus from the City to the suburbs, comprised largely of middle income families with young children. Thus, a focus of the design competition as a whole is to develop downtown housing that will attract families who have moved, or are thinking of moving, to the suburbs. It is also recognized that other client groups and specific needs might be well served by distinctive downtown housing alternatives.

In particular, as Canada's largest municipality, the City of Montreal recognizes the importance of promoting urban housing that is more sustainable from environmental, economic and social perspectives.¹ Thus the competition theme for one of the four sites will be healthy, environmentally designed housing. Participants in the competition will be asked to address this theme at several levels -- those of the housing unit, housing development, site, and neighbourhood -- and to combine innovative design concepts and technology options. In bringing the concept of sustainable housing to buildable form, the intent is to encourage a high level of innovation without sacrificing affordability and marketability.

As a key proviso, it is essential to qualify the basic goal: "sustainable housing" is the ideal, but the practical task is to develop housing that is more sustainable than current conventional housing, rather than housing that is sustainable by some absolute measure. In addition, the project should serve to *demonstrate* the possible (to designers, developers, builders, homebuyers, etc.), rather than to *experiment* with emerging potentials. Demonstration housing can be counter-productive if it is too experimentally ambitious.

1.2 Purpose of and Approach to the Paper

The primary purpose of this background paper is to provide a conceptual and substantive basis for the preparation of a background paper which will be provided to prospective participants in the design component on sustainable housing. In exploring various sustainability issues, the paper also touches on some aspects of housing which are relevant not only to designers, but to urban planners, developers, builders, building material manufacturers and others. Sustainability concerns in the housing sector arise at all phases of the housing lifecycle (from raw material extraction through to housing demolition), and in relation to siting, planning, etc.

In fulfilling its primary purpose, this paper examines the project context, and goals of and approaches to sustainability in housing. More specifically, following these introductory subsections, the remainder of Section 1 is devoted to a brief exploration of the concept of sustainability in general, and the impetus for sustainable housing in particular. Section 2 then

¹ In itself, concentrated residential development in a vital urban core is more sustainable than urban sprawl. Higher densities and greater heterogeneity (residential/commercial/business) allow for various material economies, including: reduced infrastructure needs (roads, sewer lines, etc.); lower consumption of energy and other resources per household (in multi-unit housing); and reduced travel to work, shopping, and leisure destinations. However, beyond an optimum core size, economies of scale and quality of life may begin to break down.



briefly addresses the potential demand and clientele for sustainable housing, and the characteristics that might be necessary to ensure marketability.

Sections 3 and 4 are the heart of the paper. Section 3 is the delineation and discussion of goals of sustainable housing. It sets the context for Section 4, which is an exploration of approaches to fulfilling the goals. The intent of Section 4 is not to provide an exhaustive list of techniques, but rather to offer potential competitors a practical orientation. Flowing from issues touched on in Sections 3 and 4, Section 5 offers some suggestions for the design competition.

1.3. Impetus for Sustainable Housing

a. Impacts of the urban residential sector

Because cities are the engines of contemporary economies, and therefore centres of intensive resource consumption and waste production, the urban arena is a critical focus for efforts towards sustainability. About 75% of North America's population lives in urban areas. Environmental impacts associated with the urban residential sector range from impacts of indoor air quality on the health of individual householders, to ex-urban land use and environmental quality issues related to the resource consumption and waste disposal activities of urban households. These various impacts are enormous; for example, on a daily basis, the average U.S. urban resident uses 569 litres of water and 7.1 kg of fossil fuels, and generates 454 litres of sewage, 1.5 kg of refuse, and 0.6 kg of air pollutants. The impacts of such levels of consumption and disposal are further examined in the section on goals (Section 3).

b. Sustainable development and related initiatives

The current context for efforts towards more environmentally sensitive development in all sectors, including housing, is the concept of sustainability. This concept was given enormous international impetus through the work of the World Commission on Environment and Development (summarized in the 1987 Brundtland Report). However, this concept, and tools for its application, did not arise independent of earlier work.

For instance, biological conservation, as promoted through the World Conservation Strategy and numerous other initiatives, has long been a key concern of the environmental movement.

As another example, the energy conservation and efficiency response to the energy crisis of the 1970s resulted in a considerable investment in energy-saving research and technologies. Significant progress has been made, placing Canada in a position of leadership in some sectors and technologies.² Moreover, energy consciousness has fostered a receptivity to the current theme of sustainability.

An additional key catalyst for environmental concerns has been the human health impacts of environmental stresses. While these impacts were largely brought to focus through occupational diseases, it is now recognized that exposure to stress factors occurs in our ambient environments (e.g., via urban air-quality and drinking water quality), and in indoor environments. In addition, chemical hypersensitivity (also known as environmental illness or

² On the other hand, problems arising from simplistic energy conservation goals are becoming apparent in some sectors, including housing. In particular, household operational energy consumption was the exclusive focus, and issues related to embodied energy (refer to section 3.1.a.) and to environmental externalities such as air and water pollution, were virtually ignored. Also, the focus on household energy efficiency does not directly address the real issue of per person energy consumption. Reduced consumption per square foot is to little avail if offset by a greater number of square feet per person.



total allergy syndrome) amongst a proportion of the population has come to be recognized as a consequence of increasing exposure to an ever-growing array of toxins.

Parallel to these initiatives and growing concerns, the federal government (largely through the Science Council) and various non-governmental environment groups were vigorously promoting the notion of a "Conserver Society". This concept was defined not only in terms of the physical dimensions of our lifestyle and economy (specifically, material and energy resources), but also in terms of perceived social "goods" such as decentralization of decision-making and production, labour versus capital intensity, voluntary simplicity (doing well with less), self-determination and personal growth, and ecological sensitivity (Ministry of State, Science and Technology, 1978). Conserver Society initiatives did contribute to action on energy and material efficiency, but were less successful in converting Canadians to the philosophical underpinnings.

Support for the concept of "sustainable development" is much greater than for any previous resource conservation or environmental protection initiative. The concept and its popularity reflect widespread recognition that the limits to urban-industrial growth are being reached not only in terms of resource constraints, but more emphatically in terms of the ability of the earth's natural systems to absorb continued abuses. It also reflects a growing conviction that existing inequities in the distribution of wealth, and in human well-being, can no longer be tolerated.

Definitions of sustainability abound, but fundamental concepts relate to living off the "interest" and maintaining the "capital" of the natural world, and to safeguarding the necessary conditions to sustain and promote essential and desired characteristics of the natural environment and human systems (cultural, socio-political, economic, etc.). Thus sustainability is defined not only in terms of the natural environment, but also economic and social equity, opportunity, and viability. Goals and achievements developed through energy conservation and Conserver Society initiatives are thus merged with a broader set of considerations.



2. POTENTIAL CLIENT GROUP AND ELEMENTS THAT MAY APPEAL TO THEM

Because the concept is relatively new, there is little direct knowledge about the potential clientele for sustainable housing in an urban setting. While there is not yet an articulated, market demand, given the tremendous rise in environmental and health consciousness, and the obvious desire of many individuals to take concrete action, a clientele will undoubtedly emerge when the product is seen to be feasible. Moreover, regulatory and economic changes will likely begin to drive the market towards more environmentally sound housing.

2.1. Probable Characteristics of Clientele for Sustainable Housing

It seems likely that the client group will have much in common with certain other, better understood groups, including the prevailing client group for downtown housing, buyers of energy efficient housing, and "early adopters". Selected general characteristics of these groups are discussed below.

a. Prevailing client group for downtown housing

In general, inner city living is particularly appealing to individuals who place a high value on services (versus individuals more oriented to physical goods, including space). This lifestyle emphasis is facilitated by proximity to the central business district, and to a wide variety of facilities for recreational and cultural activities, and institutional services (e.g., public transportation, education, day care, and medical facilities). Indeed, proximity of workplace to home has become a key quality of life consideration for many people.

b. Characteristics of clientele for energy efficient housing

Individuals who might purchase sustainable housing would likely exhibit some of the same characteristics and interests as those drawn to energy efficient housing.

Purchasers of R-2000 homes were predominantly between 31 and 45 years of age, and were "professionals". Fifty-seven per cent of households had two income earners. Almost half were couples with children, and another 35 per cent were two adults with no children. Most purchasers had previously owned a detached home. Homeowners were willing to pay extra for energy-efficient features (Buchan, Lawton, Parent Ltd, 1988). In fact, analysis of the R-2000 program suggests that about 10 per cent of Canadians would be willing to pay an amount in excess of the true incremental cost of such energy efficient housing if the benefits were understood (Energy, Mines and Resources, 1987).

c. Characteristics of probable "early adopters" of sustainable housing

The R-2000 initiative was a relatively highly promoted, easily rationalized, and technologically proven approach to a specific goal. The appeal of the much broader concept of sustainable housing is idealistic as well as practical.

As common sense and diffusion research (research on the process by which innovation spreads through a society) inform us, people do not all adopt innovation at the same time. From a marketing point of view, sustainable housing would probably best be oriented to environmentally-concerned people who exhibit "early adopter" characteristics. Early adopters are generally well integrated in the local social fabric, and are important sources of opinion leadership therein. Because they are respected for their use of successful new ideas, appealing to these people is key to speeding the diffusion of new ideas (Rogers and Shoemaker, 1971).

Age appears not be a relevant factor in identifying potential early adopters. In general, however, early adopters tend to be better educated, and have higher social status (as indicated by income, standard of living, occupational prestige, etc.) and a greater degree of upward



social mobility. They may also have a higher degree of "status inconsistency", for example, higher than average education and occupational prestige, but lower income. In terms of personality, early adopters tend to be cosmopolite, intelligent, motivated, adaptable, and able to deal well with abstractions. They seek information about innovations, and are well integrated in systems that keep them abreast of new thinking. They tend to have relatively high levels of social participation, and access to agents of change (other opinion leaders, mass media, etc.). Individuals who have already exhibited early adopter characteristics in relation to household environmental technologies and behaviours (e.g., low-flow showerheads, composting, reduced dependence on cars) are likely to be more receptive to innovative, environmentally-sensitive housing design.

Stages leading to adoption of innovation include awareness, interest and evaluation. Thus the targeting of potential early adopters, and the provision of ongoing information and learning/experiential opportunities to those who actively express interest, may be the best means of ensuring that the idea actually sells. Advertising to raise awareness among potential buyers should address general benefits and characteristics versus detailed technical explanations. It should be noted that for a majority of R-2000 clients, a key influence in the decision to purchase R-2000 homes was information provided by the builder.

2.2. Elements of Potential Appeal to Early Adopters of Sustainable Housing

It is reasonable to assume that some of the housing and neighbourhood characteristics desired by a broad cross-section of downtown clients would also be desired by early adopter clients for sustainable housing. In other words, an approach that would appeal to the target group would be moderately innovative, but not radical.³ Indeed, a recent study by the U.S. Department of Housing and Urban Development found that builders and buyers take between three and nine years to accept an innovative product or technology (Friedman, 1990). Some compatibility with existing standard preferences is therefore important.

In general, families buying downtown housing desire single family qualities in a high density setting. A survey of about 400 recent home buyers in downtown Montreal (Langlais et al., 1989) indicated that desired features for new housing include two stories, a patio or deck, access to a yard, large interior spaces and a private interior court. Another survey for the Fonteneau project (Hurtubise, 1991) suggests a preference for 2 or 3 bedroom houses of 100 to 140 m², with generous fenestration. Energy efficiency is also a generally desired feature of new housing. However, R2000 experience also indicates that health and comfort factors (e.g., reduced draft, reduced noise transmission, quiet operation, improved air quality) have also come to be more widely appreciated. In fact, these comfort factors may be crucial to marketability. Security is also an important consideration.

At a neighbourhood level, Hurtubise's (1991) survey indicated a preference for streets with little traffic (a majority also wanted street parking prohibited), without poles or aerial wires, and with mature trees and some green space. In general, proximity of safe play areas and daycare are characteristics of central interest to families. Easy access to services, transportation and shopping are also highly valued.

³ At the cutting edge are the "innovators": A small minority of highly venturesome risk-takers, often with above-average capability to understand and apply complex technical knowledge, and with sufficient financial resources (or financial disinterest) to absorb setbacks related to risk-taking. Innovators interested in environmental issues are likely to already be incorporating many environmental technologies and features into their households, and to be adopting appropriate behaviours. Given that true "innovators" are a very small and maverick segment of society, it may be imprudent to orient the project to this category.



Although some characteristics of general appeal are necessary, early adopters are also likely to be more amenable to less traditional features. For example, such individuals may be more willing to consider shared facilities, such as gardens, play areas and workshop space. Such features depend for their success on social skills and attitudes towards property which may not be the norm. If they are to be incorporated in a housing project, the screening of potential clients, and perhaps an active orientation effort, may well be justified.

Early adopters might also be more amenable to individual lifestyle changes, such as reducing automobile dependence by working out of the home, and/or choosing to walk or cycle to more destinations. Hence, housing features that facilitate such changes may be appealing. Similarly, it is likely that new but proven technical features that enhance the performance of the house, and thoughtful "hands on" environmental design features (such as built in recycling bins or a moveable wall) would be attractive to the early adopter client group.



3. GOALS FOR SUSTAINABLE URBAN HOUSING

Establishing goals for sustainable housing is the most crucial conceptual step. It establishes the basis for the selection of particular materials, techniques, features and design approaches.

Four major goals, and a number of ancillary objectives, are suggested:

Goal #1: Reduced Resource Consumption and Appropriate Resource Use

- Energy conservation and efficiency
- Reduced material consumption and increased re-use and recycling
- Matching of resources to uses

Goal #2: Reduced Environmental Impacts (natural and built environments)

- Reduced impacts from the production, use and disposal of construction materials
- Reduced pollutant loading in household occupancy
- Sensitive site planning

Goal #3: Improved Health and Well-Being

- Healthful housing
- Stable, healthy communities

Goal #4: Affordability and Marketability

The discussion of the goals in the following subsections is oriented to small-scale urban housing on insertion sites. Although the goals are also relevant to sustainability in larger-scale projects, issues at this level (e.g., public transit planning, integration of commercial and residential properties) are not addressed in the current paper. Similarly, issues related to site selection (e.g., avoidance of sensitive lands), are not explored.

Sustainability in housing should be approached via both direct physical measures, and measures which facilitate desirable behaviour.⁴ Moreover, although designers traditionally focus on a single phase in the lifecycle of a house, to effectively pursue improved sustainability, housing must be viewed in the context of a total lifecycle approach consisting of the following stages: raw materials extraction; processing; fabrication; transportation of materials; installation on site; operation; maintenance, repairs and replacement; and demolition. Decisions made at the design stage can in fact affect all of these lifecycle stages. All of these elements were taken into consideration in elucidating the goals.

The following subsections describe each of the goals in detail. It should be recognized that there is inevitable overlap between goals, so that in fulfilling one, achievement of others may be positively or negatively impacted. Trade-offs may be required in order to optimize on some

⁴ Housing characteristics can encourage sustainable behaviour in the realms of: lifestyle choices (e.g., composting); consumer choices (e.g., easy-cleaning surfaces may promote reduced consumption of toxic cleaners); producer behaviour (e.g., growing vegetables, working at home); and social behaviour (e.g., shared responsibilities for common facilities).



goals, but in each of the goal areas, conditions should as an absolute minimum match the standards in conventional new housing.

3.1 Reduced Resource Consumption and Appropriate Resource Use

a. Energy conservation and efficiency

Reducing the energy consumption and improving the energy efficiency of building and operating a house is probably the most critical component of improved sustainability. The fundamental emphasis should be on reduction in energy consumption *per person over the housing lifecycle*, an emphasis which must be addressed through densification and lifestyle as much as through technology *per se*.

Specifically, the key energy objectives are to:

Reduce the total operating energy of a household, and its peak energy load;

Reduce energy consumption in construction, including the energy embodied in materials; and

Stimulate energy saving lifestyles and behaviours.

In 1988, of Canada's total energy end use of 6,806 petajoules, residential end-uses accounted for about 19 per cent. In 1985, the composition of Canadian residential energy use was 51 per cent gas, 30 per cent electrical, 15 per cent oil, and 4 per cent other (D'Amour 1991).⁵

On average, two-thirds of residential end use energy in Canada goes to space heating. Other sources of energy consumption include appliances⁶ and lighting, which account for about 17 per cent of the energy used in Canadian households (about 7,000 kWh/year of electricity in the average Canadian home), and domestic hot water, which accounts for 15 per cent. Significant reductions can be achieved in all of these areas via increased energy efficiency in building envelopes, mechanical systems, appliances, and lights. This can be achieved with little, if any, lifestyle compromise.

Of particular value in terms of electricity use is reduction of household electricity consumption during periods of peak load on the system. Peak load defines the maximum requirements of the system, so reducing this load reduces the need for new electrical generation capacity. In winter, peak system load coincides with early morning and dinner-time household activities.

The embodied energy of construction materials (i.e., energy used in their production), and the energy used in construction, renovation and demolition of housing, also accounts for a significant additional proportion of total Canadian energy consumption. In fact, the total embodied energy may be equivalent to 10 to 30 years of average household energy usage. Through judicious selection and management of materials, these energy costs can be reduced. On the other hand, increased embodied energy "investments" may be warranted if good energy payback can be anticipated; in other words, if additional embodied energy -- for example, additional insulation -- can be relatively quickly recovered via reduced operational energy use.

⁵ Of the four major sectors of the economy (transportation, industrial, commercial and residential), the residential sector is the second highest user of electricity and natural gas.

⁶ Canadian homes have an increasing number of high energy appliances. By the mid 1980s over 64% of Canadian households had clothes dryers, 16% had air conditioners, and 35% had dishwashers (Statistics Canada, 1986).



Building size and form have significant implications for energy consumption in construction, materials and occupancy. Clearly, higher density developments and smaller units are inherently less material consumptive (implying less embodied energy), and because of shared walls etc., require less heating. Conscious design can take even greater advantage of these economies of scale.

Finally, building and household design can significantly influence energy and resource consuming behaviours. For example, designs that encourage shared use of equipment (e.g., a common workshop, shared laundry facilities) can contribute to a reduction in consumption. As another example, about 80% of urban travel is estimated to take place via the most energy-consumptive mode of urban transport -- the private automobile. To some extent, housing design and neighbourhood planning can reduce this dependence on the automobile.

b. Reduced material consumption and increased reuse and recycling

Reduced material consumption and increased reuse and recycling can be achieved in both construction and occupation phases. They are also essential elements of progress towards sustainability in the residential sector. The specific objectives are to:

- Reduce the consumption of total materials on site, with a particular emphasis on reduced consumption of virgin materials;

- Ensure that materials not used on site are directed to or recycled for other uses;

- Preferentially use materials that are produced with low resource inputs;

- Emphasize durability in materials and design; and

- Promote resource-conservation and materials reuse and recycling in occupancy.

Reduced requirements for construction materials can be achieved in part through the use of materials-efficient construction techniques and by avoiding unnecessary overbuilding, as well as with the above-noted economies of scale associated with compact size and form. In addition, total material requirements can be limited by reducing job-site waste. Currently, about 16 per cent of Canada's landfill waste is from the construction industry, of which 30 per cent is residential construction materials (CMHC, 1986). Per unit low-rise residential construction wastes include over a tonne of dimensional lumber and manufactured wood, a tonne of masonry and tile, 400 kg of drywall, and many other wastes (REIC Consulting Ltd et al., 1990). Lumber wastage accounts for about 10 per cent of lumber purchased for construction. These wastes -- and the associated resource use -- can be significantly reduced via improved on-site management, as well as greater use of after-markets.

Selection of materials and components with a relatively low material input to output ratio in production, and/or high recycled content, enables a reduction in raw materials extraction (and in impacts associated with such extraction). In addition, in many cases, the processing and use of recycled materials require less energy than raw materials.

Durability is of crucial importance. Durable materials and a durable house mean greater mileage out of the initial resources used in construction, as well as resource conservation via reduced maintenance requirements. Longer life helps justify investment in materials and components that reduce operating needs, since the benefits accrue over a longer period.

In terms of resource consumption associated with occupancy, housing design and detailing can encourage resource-conserving behaviour by occupants. About 33 per cent of Canada's annual 30 million tonnes of solid waste are generated by occupied households. According to D'Amour



(1991b), Montrealers throw out 400,000 tonnes of residential garbage per year. Occupancy patterns and behaviour are major factors in material efficiency. Design should facilitate reuse, recycling, and composting.

With respect to water consumption, Canadian municipal domestic water use per capita in 1983 was 360 litres per day (Tate and Lacelle, 1987), which compares very poorly with almost all other industrialized nations. The toilet is the major source of water use (about 40%), followed by outdoor uses (especially lawn watering), bathing and personal use, laundry, and cooking/drinking. There is great potential for the reduction of water consumption and wastewater generation via water conserving technologies, systems, and behaviour.

c. Matching of resources to uses

Resources can also be "wasted" if a relatively scarce and/or "high quality" resource (i.e., a resource whose attributes are necessary or desirable for relatively sophisticated applications) is used for a task which would be as well performed by a more abundant and/or lower quality resource. Thus, better match between resources and end uses is an important component of improved resource management.

For example, electricity is used for about 19 per cent of Canada's residential space heating (D'Amour 1991). The use of electricity for electric resistance heat is generally not a prudent match between resource and end use. Electricity is a highly structured form of energy required for such sophisticated tasks as lighting. Heat, on the other hand, is the most dissipate form of energy. Use of non-electric energy is therefore generally preferable to electric resistance heating, assuming that the alternative resource is environmentally acceptable. Optimally, a significant proportion of space heating requirements can be met through renewable passive solar energy.

On a broader level, maximizing the use of renewable energy sources contributes to the long-term sustainability of energy supply. Moreover, use of freely available renewable energy sources, in combination with more efficient energy use, enhances the "energy autonomy" of households, making them less vulnerable to external changes in energy availability.

For the same reasons, renewable resources can also often be used to advantage in the production of materials and goods. Renewability is an inherently desirable attribute, and use of renewables minimizes the disruptions associated with exploration and development of new sources of non-renewable raw materials. In addition, many renewable raw materials require less energy in transformation.

In general, it is also desirable in the selection of construction materials to use local materials. This contributes to local economic sustainability, and reduces energy consumption in transportation. However, the advantage of local materials may sometimes be outweighed by other considerations, including sensitivity of the local environment to disturbances created by raw material extraction and processing, and availability of more sophisticated pollution control technologies at centralized production facilities.

3.2 Reduced Environmental Impacts (Natural and Built Environments)

Clearly, environmental impacts are diminished by an overall reduction in resource use. Improved materials management will also result in reduced waste generation. However, in addition to reducing quantities of energy and material inputs in house construction and operation, consideration must be given to the differential impacts on land, and on air and water quality, from the use of various resources.



a. Reduced impacts from the production, use and disposal of construction materials

From the initial raw material extraction through to the demolition of a dwelling, impacts on land, air quality, and water quality -- and associated impacts on natural habitats, biological productivity and health -- are inevitable. To reduce these impacts, it is necessary to:

Select components that are produced from raw materials whose extraction does not cause significant, irreversible ecological damage;

Select materials whose production causes minimal soil, air and water pollution, and that do not release toxins during use or disposal.

Minimize the production of solid wastes;

There are countless illustrations of lifecycle impacts from housing materials. For example, the production of plywood involves impacts on forest ecosystems from logging, emissions of formaldehyde and/or other volatile organics during the treatment process and following installation, and land use impacts at disposal. Careful materials selection can reduce these kinds of impacts.

That solid wastes are an environmental burden is well illustrated by the ongoing landfill "crises" experienced by many municipalities. Over and above any specific land-use and environmental problems, few communities are willing to host new landfills. In fact, some jurisdictions and landfills are considering banning or restricting certain construction materials. For example, the Ontario Minister of the Environment is considering a province-wide ban on the acceptance at landfill sites of such construction wastes as wood, drywall, brick and block, thereby necessitating waste reduction strategies.

b. Reduced pollutant loading in household occupancy

To mitigate environmental impacts associated with occupant resource use it is important to:

Choose technologies that reduce the generation of pollutant emissions and effluents from households; and

Facilitate household and consumer behaviours that minimize waste and pollution.

As an example, wastewater production from household activities, and from the increased runoff that occurs when ground permeability is reduced, often result in substantial effluent discharges to waterways. While these impacts must in part be addressed at the level of municipal infrastructure, much can be done at the site and household level to minimize effluent loading. The above-noted advantages of "clean", low-emissivity materials also extend to the occupancy phase, since ventilation from homes with poor indoor air quality contributes to ambient air pollution.



Energy consumed in the operation of households is also a significant source of land impacts and air pollution.⁷ The key to mitigating these impacts, however, lies primarily with energy conservation and efficiency, as described above (subsection 3.1.a.).

Environmentally-sensitive householder behaviour can be encouraged, for example, by easy to clean surfaces and low maintenance landscaping. Such features make the use of non-toxic cleaners and natural lawn and garden care methods more practicable.

c. Sensitive site planning

Housing also impacts directly on the surrounding environment. To mitigate these impacts, site planning should:

Respect and use to advantage the attributes of a given location; and

Compensate for detrimental features.

At the broadest level, residential development involves extensive use of land, thereby abrogating inherent and other potential use values of the land. Densification is one means of containing land-use impacts. At a more refined level, sensitive planning would aim, for example, to preserve existing trees, maximize green space (within constraints imposed by higher density), and respect existing architectural styles. Compensating for detrimental features might involve, for example, the landscaping of areas that were previously paved, or the replacement of lost green space with rooftop gardens.

3.3 Improved Health and Well-Being

a. Healthful housing

Housing should, at the least, avoid impairing and, at best, contribute to human health. Specific goals are to:

Minimize occupational health risks associated with production and use of materials, and with construction in general;

Minimize physiological stresses (e.g., air pollutants, noise, electro-magnetic radiation) for occupants; and

Create the potential for healthy and enjoyable lifestyle choices.

Products that pose occupational health hazards in their production, use/installation, removal, repair, or decomposition should be avoided. Efforts should also be made to minimize physiological stresses on household occupants via appropriate housing design and choice of materials. Indoor air quality can be a crucial factor for the health of household occupants, as poor quality can result in symptoms ranging from general discomfort to allergies to environmental hypersensitivity. Six main sources of contamination of indoor air are:

⁷ Consumption of energy in household operation necessitates fossil fuel extraction and refining, and electricity generation, which result in extensive land impacts. By end-use category, residential heating is the second largest source of CO₂ emissions -- at about 100 megatonnes, it is less than the emissions from industrial process heat, but about on par with emissions from private vehicles (John Robinson, unpublished). There are also emissions of sulphur dioxide, nitrogen oxides, carbon monoxide, and other pollutants associated with residential energy consumption. Though the residential sector is not one of the major source of these pollutants, the effects are concentrated in the winter months, and in areas of high population density.



- Combustion products (e.g., particulates, CO, NO_x);
- Off-gassing from building materials themselves and emissions and irritants from household contents (e.g., formaldehyde and other VOCs from plastics, paints, floor coverings, particle board, cleaning materials etc.)
- Biological processes (animal dander from pets, pollen from plants, etc);
- Moisture and associated moulds (e.g., from condensation, basement flooding, etc.);
- Soil gas (e.g., methane, VOCs, and other pollutants from contaminated sites or landfills, and also radon); and
- Outdoor air.

The amount of time spent indoors in a climate such as Montreal's exacerbates indoor air quality problems. The key is to improve air quality by minimizing pollution at source. Proper ventilation is of course also necessary, particularly in the well-sealed housing that is so attractive from an energy efficiency viewpoint. But the primary function of ventilation should be removal of basic occupancy pollutants, rather than removal of building materials pollutants, or avoidable occupancy pollutants. Source reduction of pollution from building materials can be achieved by avoiding synthetic materials with high off-gassing levels. Ease of cleaning, such that dust levels are minimized and non-toxic cleaners can be used, also contributes to source reduction.

Noise pollution can cause distress, particularly in high density, urban settings. Site orientation, design and selection of components should, without compromising other sustainability criteria, be used to reduce sound transmission.

Finally, healthy lifestyle options (e.g. exercise, gardening) can be encouraged through design.

b. Stable, healthy communities

With the changing social structures and related changes in households (e.g., loss of extended family support, increase in single parenthood, live-alone elderly), many people face a high degree of isolation and stress. Housing and neighbourhood design can facilitate the development of supportive community relationships.

Subtle relationships exist between community stability, community cohesion, and sustainability. Stable multi-generational communities lead to the development of networks of mutual support that are more likely to satisfy the needs of members internally, reducing reliance on distant and/or institutionalized support systems and infrastructure. (One of the goals articulated in Montreal's new residential policy is to promote conditions which allow people to remain in their milieu.) Housing design that promotes the sharing of leisure activities, as well as certain tasks and responsibilities, may also contribute to healthy relationships and interdependencies.

Housing that is adaptable to changing circumstances and needs can contribute to community stability: examples include designs that facilitate "aging in place" via homesharing, or accommodation for changing family size and changing work patterns (e.g., working from the home). Moderate density, mixed use neighbourhoods may make for a more convivial and stable community, because more activities can take place close to home.



3.4 Affordability and Marketability

To be of practical significance, sustainable housing must be at the affordable end of spectrum. It should also offer manageable occupancy costs and long-term resale value.

Greater up-front affordability may result from a wide variety of sustainability characteristics, including: smaller lot size; smaller housing unit; efficient resource use; and substitution of local materials. During occupancy, features such as durability, ease of maintenance (e.g., absence of need for ongoing treatment of surfaces) and ease of repair and renovation (e.g., easy access to service lines), should contribute to affordability. (At the end of the lifecycle, recoverable materials can result in credits at the demolition stage.)

Adaptability may contribute to marketability. Made-to-convert housing can more readily appeal to a wide market segment, including the elderly, single parents, professional couples, empty nesters and small families. Marketability could also be improved by features which increase the sense that the house is "taking care" of the occupants. The importance of comfort factors has already been noted. Additional features might include mechanisms that provide feedback on the house's performance, such as energy use, ventilation rates, and air quality. Performance testing and associated performance labelling can also contribute to consumer confidence. In general, the operation of mechanical, feedback and control systems should be as transparent as possible.

Finally, as availability and awareness grow, there is every likelihood market demand for sustainable housing will be stimulated.



4. REVIEW AND ANALYSIS OF APPROACHES TO MEETING THE GOALS OF SUSTAINABILITY

To summarize from the preceding section, the four key goals for sustainable housing are:

- Goal #1: Reduced Resource Consumption and Appropriate Resource Use**
- Goal #2: Reduced Environmental Impacts (natural and built environments)**
- Goal #3: Improved Health and Well-Being**
- Goal #4: Affordability and Marketability**

For housing to become more sustainable, these goals must be addressed wherever possible. Specifically, these goals should be translated into decisions and actions related to:

- a. Selection of materials, components, and appliances**
- b. Selection and design of building and household systems**
- c. Architectural design considerations**
- d. Site Planning and integration with the local milieu**

These elements of house design and construction are the major topic headings for the following discussion on approaches for developing sustainable housing. In order to systematically explore approaches, under each of the four elements, examples of how to achieve each of the goals are explored.

Given that the four elements are massive and complex topics, what follows under each element is a brief summary of key features, and some illustrative examples, relevant to the achievement of each goal. It should be recognized that not all of the goals are equally applicable in each of the four categories, and, in some cases, two or more goals may be addressed through the same set of features.



MATERIALS, COMPONENTS, AND APPLIANCES

Goal #1: Reduced resource consumption and appropriate resource use

Key Features: Has low embodied energy; contributes to energy conservation and efficiency in household operation; minimizes raw material use; is durable; is based on renewable resources; has a high recycled content; is reusable or recyclable; is produced from local materials.

Examples: Wood-frame construction: This form is based on a renewable resource and is of relatively low energy intensity compared to concrete or steel.

Materials-efficient construction: Use of lighter grade materials where applicable; use of engineered/manufactured/pre-assembled components such as trusses; use of finger-jointed studs where possible.

High-performance windows: An example is a triple glazed unit with a low emissivity coating, and with sealed, argon-filled spaces between the glazings, and non-conductive spacers.

Recycled materials: For example, cellulose insulation (produced from recycled paper), scrap lumber, and materials that use industrial waste.

Fluorescent lighting: A typical incandescent bulb converts only 15% of electricity to light, the rest being waste heat. Compact fluorescents require 75% less energy. In high-use areas, fixtures should only accept compact fluorescent bulbs. Where incandescent lighting is used, dimmer switches are desirable.

Energy efficient appliances: For example, front-loading clothes washers are available which heat their own water, and are generally about 35 per cent more efficient than top-loading washers, and also save water.

Energy efficient motors: For example, fractional horsepower motors for fans, etc.

Water conserving technologies: These include efficient toilets, low flow showerheads, faucet aerators, and underground irrigation for the garden (to minimize evaporative losses).

Solar technologies (e.g., photovoltaic panels) for certain applications (e.g., exterior lighting, water heating).

Management at the construction site: While not directly related to material selection, much can be done during construction to minimize material waste. A management plan to deal with construction wastes is desirable. Reduced consumption of total materials on site requires care to avoid ordering excess materials, and to prevent damage to materials during construction. Framing design and cutting practices for dimensional lumber can be oriented towards minimizing wastage. Certain materials can also be re-used on site, such as crushed brick for backfill, and drywall waste for additional mass in south



facing-partition walls. Finally, there should be reuse or recycling of materials off-site. This is made easier by selecting materials known to be in demand, and known to be reusable or recyclable with existing, widely available technologies (e.g., undamaged shingles for reuse, corrugated cardboard for recycling). Materials management also involves on-site separation of materials, and coordination with off-site users, resale brokers, and recycling depots. There should be separate on-site bins for recyclable wastes such as drywall, wood, metals and landfill materials. To the extent possible, subcontractors should be responsible for managing the wastes from their work (e.g., drywallers should be responsible for drywall wastes).

Goal #2: Reduced environmental impacts

Key Features: Involves minimal impacts in raw material extraction (e.g., uses renewable resources from well managed systems); causes minimal pollution in production, use and disposal.

Examples: Locally-grown wood versus tropical hardwoods.

Materials and components which do not use toxins or release pollutants in production, and have low off-gassing potential. (Again it deserves note that indoor air quality problems are vented to the outside.) Examples include additive-free, non-toxic concrete and plaster products, and non-toxic water-based or latex paints versus enamel or oil-based.⁸ Non CFC insulation minimizes damage to the ozone layer.

Construction site waste management should include a properly designed storage/disposal container for hazardous wastes.

Goal #3: Improved health and well-being

Key Features: Improves, or at a minimum does not impair, air quality; is non-allergenic; is easy to clean; contributes to comfort.

Examples: Air-vapour barriers: Help to control infiltration of outdoor pollutants, and chemicals from materials in the building envelope.

Use of materials or techniques (e.g., fail safe devices) which prevent heating system backdrafting and spillage of combustion gases; in particular, ensuring that air-exhausting devices (e.g., central vacuums) do not depressurize the house.

Sound barrier materials.

Ceramic tiles or other hard surfaces versus carpet: These surfaces result in lower dust levels. Also, easy-to-clean surfaces may result in reduced use of toxic cleaners. Materials that do not require constant application of finishes (oils, waxes, etc.) are also desirable.

Building materials with low radium content.

The low off-gassing materials mentioned under goal #2 also help minimize health stresses.

⁸ Environment Canada's Environmental Choice Program endorses low-toxicity paints with its EcoLogo.



Goal #4: **Affordability and marketability**

Key Features: Has reasonable up-front cost; contributes to reduced operating costs; is durable.

Examples: High-performance windows: While initial costs are about 30 per cent higher, payback is estimated at 3 to 6 years.

Fluorescent lights have a payback of under five years, and last longer than incandescents.

High RSI insulation for ceilings, attics, and walls has relatively low cost and good payback.

Many efficient appliances also have a pay-back well within their lifetime.



BUILDING AND HOUSEHOLD SYSTEMS

**Goals #1:
and #2** **Reduced resource consumption, appropriate resource use, and reduced environmental impacts**

**Key
Features:** Contributes to energy conservation and efficiency; reduces energy consumption during peak system load; contributes to water and resource conservation; contributes to use of renewable resources; encourages re-use and recycling; is durable; enhances durability/longevity of building.

Examples: Airtight and energy efficient building envelope: Air-tight construction improves energy efficiency, and prolongs the life of the structure by reducing the potential for condensation within the frame. An example of an effective air barrier is sealed polyethylene installed behind the drywall. The exterior moisture barrier and interior drywall are secondary barriers. A high level of insulation is also necessary.

Alternative heating systems: Passive solar space heating, solar hot water heating, ground source heat pumps, thermal storage and cooling, and high-efficiency furnaces are among the technologies that have been successfully incorporated in residential heating systems. Potential also exists for alternatives at the building or neighbourhood level, such as collective or district heating systems and co-generation. Efficiency of heat distribution systems (e.g., improved duct runs, better insulation, etc.) is also important.

Integrated mechanical systems: At its most basic, this involves combined space heating and water heating (e.g., integrated condensing gas system). More sophisticated integrated heating/ventilation systems can -- with heat recovery ventilators, heat exchangers, heat pumps, and thermal storage -- recover and store "waste" heat from exhaust air, appliances, greywater, and solar gain. Proper ventilation also improves air quality. Better quality, more durable components (e.g., burner, blower) can be used in integrated systems because fewer components are needed.

Demand-control ventilation: There are three distinct ventilation needs: Ventilation of building off-gassing; ventilation of occupant-related air quality burdens; and ventilation of specific pollutants at source (e.g., shower humidity). It is possible to reduce ventilation, and the associated energy consumption and energy losses, when the occupants are away and/or when ventilation needs are low. Occupancy or pollution sensors can be used to provide the control feedback (e.g., CO₂ or activity sensors). However, demand-control ventilation only makes sense if there are relatively low building ventilation requirements. (If building ventilation requirements far outstrip occupancy ventilation requirements, little reduction in ventilation is possible.) Thus, building materials with low emissivity must be used. In terms of specific source needs, it is important to match technologies to needs. Multi-speed range hoods allow selection of appropriate level of ventilation over kitchen appliances. Bathroom fans should be such that they are only used when needed.

Dynamic wall approach: This technique was pioneered in Sweden. The walls are constructed to allow for low flows of air. The walls act as filters, and



incoming air through is warmed as it passes through the wall, thereby reducing conductive losses.

Control systems: Electrical load management systems, such as timing devices and switches, can be used to limit electrical consumption during periods of peak system load. Programmable thermostats and/or CO₂ or activity sensors for demand-control heating and ventilation reduce needless energy consumption.

Appropriate plumbing/water systems: Grey water recycling for outdoor uses and toilet flushing involves a two pipe system for separating potable water from non-potable. Rainwater catchment can also contribute to outdoor uses. Plumbing systems should also incorporate the water-saving technologies noted under the materials, components and appliances section.

Efficient lighting systems: Daylighting should be maximized. Wattage should be adjusted to need. There should not be too many lights on one switch (a particular risk with track lighting), since dividing lights onto separate switches allows independent lighting of different areas. Efficient use of task lighting is also important.

Waste management systems: Built-in recycling, hazardous waste, and composting bins, if well designed and positioned for easy access, and for easy transfer to collection site or composter, should encourage environmentally conscientious waste management. In multi-unit dwellings with minimal garden space, a relatively odourless worm bin may be the most appropriate composting technology.

Goal #3: Improved health and well-being

Key Features: Does not generate indoor pollutants; enhances indoor air quality; enhances occupant comfort; contributes to aesthetic quality

Examples: Effective air ventilation, circulation, filtration and purification systems: Ventilation systems bring in fresh air and exhaust stale air. Proper ventilation is important in order to avoid air quality problems associated with increased air tightness. Strategic use can be made of local exhaust systems (e.g., multi-speed range hoods over kitchen appliances), central exhaust systems, or heat recovery ventilators. The garage should be sealed separately from the residence. Ventilation intakes should be placed away from car exhausts, and other toxic areas.

Air-tight construction contributes to greater comfort and health by eliminating drafts, reducing noise transmission, and reducing soil gas entry.

Low temperature radiant heating contributes to comfort.

Floor and ceiling assemblies: These should be designed for reduced sound transmission (e.g., floating floors where there is to be no carpeting).

Ventilation systems equipped with mufflers, sound dampening materials, flexible mounting materials; large ducts.

Goal #4. Affordability and marketability

Key Features: Has reasonable up-front cost; has short pay-back; reduces operating costs; is durable.



Examples: Many of the examples offered above help to enhance affordability via conservation and efficient use of resources. For example, air-tight construction requires minimal increased cost, and soon pays for itself in improved energy efficiency. Integrated mechanical systems, by combining space heating, domestic water heating, and ventilation in a single piece of equipment, can replace the furnace, hot water tank, air conditioner and ventilation system. Moreover, they can save large amounts of energy via heat recovery and may, therefore, have a relatively short pay-back period.



ARCHITECTURAL DESIGN CONSIDERATIONS

Goal #1: Reduced resource consumption and appropriate resource use

Key Features: Contributes to energy and material conservation and efficiency; enables increased use of renewable resources; encourages resource-saving occupancy behaviour.

Examples: Building form and size, densification: Design that minimizes surface to volume ratio and maximizes shared wall area (e.g., compact shape, multi-unit buildings) is inherently more resource and energy efficient.⁹ Multi-unit buildings share piping, wiring, wall materials, roofing materials, etc., and therefore consume fewer materials per square metre. Increased density resulting from smaller unit size permits creation of more units, and/or retention of open space in the project. To make effective use of smaller space, some rooms should be multi-purpose. A moveable wall would enhance space flexibility.

Solar design: Passive solar can quite readily contribute 40 per cent, and even as high as 60 per cent, of space heating requirements. Building and unit design and detailing affect thermal gain, thermal storage, heat distribution and summer ventilation. Optimal layout would give as much direct sun as possible to primary living areas. Living rooms, for example, should be on the sunny side, while service rooms can be in the shade. Consideration should be given to use of sunspaces, atria, etc. on the south side of the house for lighting and heating benefits. However, care must be taken to avoid overheating in summer and energy loss in winter, a problem common to many existing poorly-designed sunspaces. Unheated sunspaces can serve as a buffer zone between the out of doors and the inside of the house.

Air conditioning: Design should eliminate, or at least minimize, the need for electric air conditioning. Consideration should be given to cross-ventilation for the summer. Roof overhangs can be used to shield south facing windows in the summer, while allowing full exposure to the lower winter sun. Other shading strategies are required for east and west facing windows.

Other energy efficiency measures: Eliminating projections from the building (e.g., bays) decreases heat loss. Heat loss can also be avoided by minimizing detailing that creates thermal bridges. An air-lock vestibule between two entrance doors can minimize heat loss when entering or leaving the building. Design should allow for effective use of a clothes line.

⁹ On a larger scale, densification also reduces both municipal infrastructure requirements (e.g., roads, sewer line) and average auto mileage per household.



Shared Facilities: Although space limitations and the importance of marketability may not allow for fully developed co-housing¹⁰ in the present project, there is potential for some shared space and facilities. Elements that are likely to be feasible include shared garden, laundry facilities, workshop/hobbyroom, playroom, and cold cellar. Such shared facilities offer environmental benefits, and are likely to be superior to the facilities than could be provided in a single household. It should be noted that in-city recreation-related auto use is as high as 20 to 30 per cent of all auto mileage, so that a spin-off benefit of shared, enhanced playrooms, hobbyrooms and gardens may be a reduction in auto use.

Rooftop garden: In recent years, numerous innovations have enabled extensive use of city rooftops for gardening, a space-efficient means of incorporating green space into urban landscapes.¹¹ Such gardens can yield produce for the household (and potentially for the neighbourhood). Other benefits include reduced dependence on transportation, both of produce into the city, and of householders to stores or markets. The garden could also help to keep the building cool in summer.

Cold cellar: This would allow storage of fruits and vegetables year round, and would thus permit bulk buying, thereby reducing gas consumption for shopping, and minimizing packaging waste.

Home office: Well-designed office space in the home may encourage more working at home, reducing energy consumption in commuting.

Goal #2: Reduced environmental impacts

Key Features: Sensitivity to impacts of design on microclimate, runoff, and other natural processes; integration of facade with existing streetscape.

Examples: In general, environmental impacts are related more to material selection and site planning than to the building per se. However, a sensitivity to the local environment is important. For example, microclimate impacts caused by solar absorption and reflection, and interference with wind patterns, should be addressed. Storm runoff can also be partly managed with building design. For example, the water-retaining capacity of soils in a rooftop garden versus a bare roof means reduced runoff, thus reducing stormwater loading of sewage systems.

¹⁰ Co-housing, a collaborative living strategy pioneered in Denmark in the early 1970s, aims to achieve a degree of social and economic advantage through quite extensive shared facilities and activities, while at the same time allowing for much of the privacy and independence of modern single-family housing. It often involves a common kitchen, a safe playing area for the children, shared guest rooms, and shared workshop and laundry facilities. In larger developments it may involve a common house with kitchen, dining area, play room, teens' room and garden.

¹¹ For example, researchers with the Gaia Institute in New York have developed a super-efficient organic rooftop gardening system using a lightweight soil (with recycled styrofoam as a key component), an irrigation system carrying a slurry of composted kitchen wastes, and a simple greenhouse. Buildings must be designed to support the weight of the soil, although the lightweight soil developed by researchers at Gaia weighs only 320 kg per cu m (generally well within roof stress loads).



The building facade should be attractive, and integrate well with the existing streetscape, without contravening energy efficiency criteria. This may pose an interesting architectural challenge.

Goal #3: Improved health and well-being

Key Features: Does not pose health threats; contributes to aesthetic quality and psychological health; encourages healthy activity; encourages social integration.

Examples: Health and safety features: Fire-proofing and fire-escapes must be attended to, and dangerous ledges, projections or other features avoided. Dust levels can be affected by ease of cleaning, so hard to get at "nooks and crannies" should be avoided.

Aesthetic features: Many of the design approaches and features recommended above would also contribute to the psychological well-being of the housing occupants. For example, recommended solar design features would contribute to the brightness of high-use living spaces. Windows are a psychologically very important component of cold-climate housing. Maximized natural light levels can minimize symptoms associated with seasonal affective disorder. Use of sunspaces as "buffer zones" between the inside and the out of doors can have a noise-dampening effect.

Visual and acoustic privacy: This is a key consideration with densification. Windows should be oriented to allow for privacy without curtains.

Lifestyle features: Gardens can be both psychologically beneficial, and confer potential health benefits via exercise, fresh foods, etc. A rooftop garden of sufficient size (e.g., spanning more than one unit) could also provide part-time employment. Features that encourage walking or cycling would also have positive health benefits.

Community-building: In terms of social well-being, shared facilities offer the potential for functional community living to people of a diversity of ages, familial structure and needs.

Adaptability: Ease of renovation for changing household needs contributes to the potential for a stable, multi-generational community. For example, it should be relatively easy to create separate apartments within a given unit. There may also be potential for interchangeable or "moveable" space within and possibly between housing units. For example, with minor design adaptations, a bedroom between two units could be annexed by either one, depending on need.

"Friendly" facade: A pedestrian "face" to the building (e.g., incorporation of street-accessible seating arrangement, use of planters) can contribute to a sense that the building is part of the larger community.

d. Affordability and marketability

Key Features: Has reasonable purchase price; has reasonable occupancy costs; is adaptable; has good resale potential.

Examples: Optimized use of existing technologies and building trades, for example, by minimizing the execution time for drywalling, plumbing, etc., helps keep the costs down (Friedman, 1990).



Narrow frontage and small house and lot size help reduce property costs and taxes.

Many of the features already described could contribute to both reasonable purchase price and lower occupancy costs. For example: effective solar design would reduce heating costs; densification and shared facilities could reduce up-front and maintenance costs. Shared facilities make possible the inclusion of features (e.g., hobby-room, cold-storage) which might not be feasible or affordable for individual units. Developments with such features could make use of a variety of ownership structures, including condominium and cooperative. Adaptable design implies that the redesign of space can take place with minimum waste of materials and low labour costs.



SITE PLANNING AND INTEGRATION WITH THE LOCAL MILIEU

With respect to context, the urban residential milieu is a composite of layers, from the individual household to the street, neighbourhood, and city district. Impacts associated with the residential sector must therefore be addressed in part via neighbourhood and urban planning. However, given that the small scale of the proposed development provides little potential for intervention at the level of neighbourhood planning and design, the appropriate emphasis is on site planning, and adaptation of the housing project to the local context.

Goal #1: Reduced resource consumption and appropriate resource use

Key Features: Uses lot characteristics/features to minimize resource consumption in construction and occupation; creates features to reduce resource consumption; promotes resource-conserving behaviours.

Examples: Building Orientation: Optimal building orientation may not be possible given lot constraints, but key factors in increasing heat gain surfaces and reducing heat loss surfaces include optimum winter sun orientation, favouring south-facing windows and solar walls, and minimized winter wind exposure. It generally makes sense to optimize for solar benefits, since landscaping can contribute to wind protection.

Landscaping for energy efficiency: Deciduous trees or shrubs can be planted along south-facing exposures to reduce the need for energy-intensive cooling in the summer, while maximizing solar gain in winter. Evergreens can be placed along exposures facing the prevailing winds, to provide winter windbreaks. Short, wide trees generally give better protection and shade patterns.

Landscaping for water efficiency and low inputs: Use of native water-conserving plants (e.g., wildflower "lawn") allows rain-fed landscaped spaces to thrive. If there is to be irrigation, greywater and rainwater should be used. Landscaping requiring minimal inputs of chemical fertilizers and pesticides, and a minimum of energy-intensive maintenance, is desirable. (Currently, on a per hectare basis, Canadians apply more chemical fertilizers and pesticides to their lawns than do farmers to crops.)

Reduced reliance on the automobile might also be encouraged by providing safe, accessible bicycle storage, safe access onto bicycle routes, and direct access to bus stops.

Goal #2: Reduced environmental impacts

Key Features: Maintenance of existing landscape, historical, and symbolic features; development of features to reduce physical impacts; creation of "habitat".

Examples: A construction-site management plan can be developed to help preserve existing attributes of the site. This could emphasize sensitive construction techniques such as shallow trenching around trees to protect roots.



Care should be taken to avoid impairing the solar access of neighbouring buildings.

Existing pedestrian access (e.g., thoroughfares to parks, bus stops, commercial establishments) should be maintained.

Intensification of run-off and erosion should be avoided by counter-balancing the creation of impenetrable surfaces. This can be partly accomplished via materials and systems -- e.g., rainwater catchment systems -- and by building design features, but landscaping is also important.

Landscaping can also create urban habitat for songbirds and other desired wildlife. If other trees or shrubberies exist in the vicinity, linking them with similar landscape features on the project site can create larger "green corridors" which will be attractive habitat.

Goal #3: Improved Health and Well-Being

Key Features: Does not pose health threats; contributes to aesthetic quality and psychological health; encourages healthy activity; encourages social integration.

Examples: Health and Safety: The site should be free of any features that might cause or contribute to injury.

Health-conscious landscaping: Plants with allergenic pollens should be avoided

Aesthetics: Some of the above-described features would ensure that the development made a positive contribution to psychological health and to community. For example, pleasing landscaping could create spaces that encourage neighbourhood interaction. The spatial cohesion created by pedestrian access also contributes to a sense of community and well being.

Goal #4: Affordability and Marketability

Key Features: Contributes to reduced operating costs; is low maintenance; has features that are easy to repair or renovate.

Examples: Landscaping for energy-efficiency would contribute to reduced operating costs.
Use of hardy, local species would reduce the need for maintenance.



5. CONCLUSIONS: IMPLICATIONS FOR THE COMPETITION

The design competition on sustainable housing will be posing a rather unique and multifaceted set of goals to the architect. Similarly, determining the relative merit of the various submissions will pose a difficult task for the judges. Several considerations should be borne in mind in establishing the terms of the competition, and the basis for appraisal.

Firstly, in considering the objectives and the methods of the design competition, it is important to remember that both the concept of sustainability itself, and its application to the housing sector, are complex subjects. It is broadly agreed that sustainability must be addressed on environmental, social and economic grounds, but both fundamental principles and practical orientations are still evolving. The goals of sustainable housing may be modified or expanded as our understanding of sustainability, and of the environmental, social and economic dimensions of housing, develop.

Nonetheless each of the goals recommended in section 3 of this paper is considered to be an important component of sustainability. While prioritizing these goals is difficult, in general terms, taking as a baseline the type of housing that would normally be built on the site in question, important advances in sustainability would be achieved if there were significant reductions in lifecycle energy consumption, in the solid waste stream associated with construction, and in environmental impacts of materials production and use, without sacrifices in relation to the other goals and objectives.

Secondly, it must be recognized that the competition will be asking the architect to consider aspects of housing development that may not be within the realm of a conventional design competition (for example, specification of some of the materials, components, appliances, and systems mentioned in section 4). Similarly, architects are not normally responsible for materials management at the construction site. It may nonetheless be appropriate to require competitors to extend their consideration beyond the strict boundaries of architectural design and into more detailed questions of building materials, household technologies, systems, and materials management. Given this, and given the growing availability of databases and tools to assist in environmental design, it could be valuable to offer prospective competitors an orientation session, perhaps using resource people from CMHC.

Finally, the specific approaches suggested in section 4 of this paper are clearly not a comprehensive set. Many other examples exist, and there are infinite combinations of specific features and design approaches that can contribute to sustainability in the housing sector. Competitors will need to combine disparate features into a holistic approach in which individual components complement each other. Even more broadly, an understanding of relationships between the external environment (e.g., climate, soils), the physical structure (e.g., orientation of the building, the building envelope, envelope detailing,) mechanical systems (ventilation, heating, etc.), occupation patterns (e.g., energy use patterns), and outcomes (e.g., energy efficiency, building durability, moisture levels, occupant health) is very important. It must also be recognized that trade-offs in approach must sometimes be made, since a feature may make a positive contribution to one of the sustainability goals, but negatively affect another.

Given all of the above, it would be very difficult to develop a set of rigid criteria by which to judge competitors' success in achieving the goals of sustainable housing. Because of the range and complexity of issues and approaches, an emphasis on goals rather than specific techniques is most appropriate in establishing both directions for the competitors, and the judging criteria. It might be appropriate to require a written component to the submission, explaining how various features of the project contribute to the goals outlined in section 3. The alternative of a set scoring scheme poses a number of very significant challenges, whose resolution may be beyond the scope of the competition. If such a system were to be used,



however, rating should be "modular", rather than attempting to arrive at a single numeric rating.

Ultimately, the competition will make an important contribution towards sustainability in the housing sector if it results in an accessible and appealing demonstration project. Benefit would also be derived if some of the challenges of sustainability for other interested parties (planners, regulators, members of the building trades, etc.) are clarified.



SOURCES

Adolph, Jonathan. Greening our cities. *New Age Journal*, pp. 34-43, November/December 1990.

Buchan, Lawton, Parent Ltd. *Results of the R-2000 Homeowner Survey*. Prepared for the R-2000 Home Program. Energy Conservation Branch, Energy Mines and Resources Canada. August, 1988.

Canfield, Christopher, ed. *Ecocity Conference 1990*. Report of the First International Ecocity Conference, March 29-April 1, 1990. Berkeley California, Urban Ecology.

Canadian Mortgage and Housing Corporation. *Housing Issues in the 1980s and 1990s: Factors which affect structural adjustments*. Background Paper for the Canadian Home Builders' Association 43rd National Conference/Exposition. February 1986.

D'Amour, David. *Sustainable Development: Its Origins and General Relevance to Canadian Housing*. CMHC Housing, Environment and Economy Project, Research Paper No. 1. CMHC Research Division, January 1991.

D'Amour, David. *Sustainable Development and the Canadian Housing Sector: Towards an Investigation of Sustainable Housing*. CMHC Housing, Environment and Economy Project, Research Paper No. 2. CMHC Research Division, March 1991b.

Desfor, Gene et al. Patterns of urban energy utilization. In *Considerations and Opportunities for Energy Conservation in Urban and Regional Planning*. Conference Proceedings, Queen's University, Kingston. 1979.

DiChristina, Mariette. Canada's Energy Miser. *Popular Science*, pp.94-97, December 1990.

Drerup Construction Limited. *Housing for the Environmentally Hypersensitive*. Prepared for the Research Division of Canadian Mortgage and Housing Corporation. July 1990.

Energiteknologi. *Energy i Arkitekturen (Energy in Architecture)*. 1990.

Energy, Mines and Resources. *Super Energy Efficient Home Program (SEEH): Program Evaluation Study, Overview Report*. Program Evaluation Group, Report No PE 115/1987. August 1987.

Hancock, Dr. Trevor. *Towards Healthy & Sustainable Communities: Health, Environment & Economy at the Local Level*. Presentation at the 3rd Colloquium on Environmental Health, Quebec. November 22, 1990.

Hurtubise, Jules. *Project de demonstration Fonteneau*. Montreal, Fevrier 1991.

Langlais et associes. *Sondage aupres des recents acheteurs de logement dans le centre-ville de Montreal*. Prepare pour Le service de l'habitation et du developpement urbain, ville de Montreal, Mai 1989.

Marbek Resource Consultants. *Household Environmental Indicators: A Feasibility Study*. Prepared for the Sustainable Development Branch, Environment Canada. February 1990.

Marbek Resource Consultants. *R-2000 Homeowner Survey*. Prepared for Energy Pathways Inc, September 1987.

Ministry of State, Science and Technology Canada. *The Conserver Society: The Technological Challenge*. Background Papers. 1978.



Netherlands Ministry of Housing. *Human Settlements and Sustainable Development in the Netherlands*. Directorate General for Housing. n.d.

Raab, Karl H. *Strategies for Healthful Residential Environments*. Vancouver, June 1984.

REIC Consulting Ltd, Renova Consultants, RIS Ltd. *Making a Molehill Out of a Mountain*. Prepared for the Toronto Home Builder's Association. Interim Report, October 12, 1990.

Robinson, Terry. *Sustainable Housing for a Cold Climate*. Research Division, Canada Mortgage and Housing Corporation.

Rogers, Everett M. and F. Floyd Shoemaker. *Communication of Innovations: A Cross-Cultural Approach* (Second Edition). The Free Press, MacMillan Publishing Co., New York, 1971.

Statistics Canada. *Human Activity and the Environment: A Statistical Compendium*. Structural Analysis Division, Analytic Studies Branch. Ottawa, Department of Supply and Services, 1986.

Ville de Montreal. *Habiter Montreal*. April 1989.

Wilkins, Anne. Canada's Advanced House Demonstration Project. CADDET (IEA/OECD) Newsletter No.4, 1989.



SELECTED BIBLIOGRAPHY AND LIST OF SOURCES

Supplement to the report entitled

Sustainable Housing: A Background Paper for the City of Montreal's Proposed Design Competition

Prepared by Marbek Resource Consultants
for the Project Implementation Division,
Canada Mortgage and Housing Corporation

BOOKS, ARTICLES AND OTHER PRINTED MATERIAL

Allen Associates and Marbek Resource Consultants. *Passive Solar House Designs for Canada*. Prepared for the Research Division of Canada Mortgage and Housing Corporation, 1989.

A practical overview of principles and design techniques for passive solar housing.

Canada Mortgage and Housing Corporation. *Energy-Efficient Housing Construction*.

Basic introduction to the principles and practices employed in recent (new generation) energy efficient housing construction.

Canadian Home Builders' Association. *R-2000 Builders' Manual*.

A guide to the design and construction of affordable housing with low space heating requirements.

Drerup, Oliver, et al. *Housing for the Environmentally Hypersensitive: Survey and examples of clean air housing in Canada*. Prepared for the Research Division of Canada Mortgage and Housing Corporation, by Drerup Construction Ltd. July 1990.

Energy, Mines and Resources Canada. *The House as a System: Training Workshop*. Participant's Kit. March 1986.

Haviland, David S., ed. *Life Cycle Cost Analysis: A Guide for Architects*. Washington: American Institute of Architects, 1977.

Presents a technique for analyzing all relevant economic consequences of design decisions.

Knowles, Ralph L. *Energy and Form: An Ecological Approach to Urban Growth*. Cambridge, Massachusetts, MIT Press, 1974.

Addresses site planning issues related to natural cycles (especially solar) for individual buildings as well as for settlements.

Lam, William. *Sunlight as a Formgiver for Architecture*. New York: Van Nostrand Reinhold, 1986.

Examples, illustrations and discussions relate to potentials for using sunlight in buildings.

Marbek Resource Consultants. *Air Sealing Homes for Energy Conservation*, second draft. Prepared for the Saskatchewan Research Council as part of Energy, Mines and Resources Canada's Buildings Energy Technology Transfer Program.

Marbek Resource Consultants. *Insulating Basements, Crawl Spaces, and Slabs-on-Grade*. Prepared for Energy, Mines and Resources Canada, Ottawa, 1987.

Mattock, Chris and David Rousseau. *A Survey of Ventilation Systems for New Housing*. Produced by Habitat Design + Consulting Ltd, Vancouver, for Canada Mortgage and Housing Corporation, External Research Project. September 1988.

Metz, Don, ed. *The Compact House Book*.

Presents the 33 prize winning designs of a competition oriented to low energy, modest cost, small houses.

1991 Consumer Guide to Home Energy Savings.

Lists efficient products (household equipment, mechanical equipment, appliances), provides performance ratings, and provides information on maximizing benefits.

REIC Consultants Ltd, Renova Consultants, and RIS Ltd. *Making a Molehill Out of a Mountain*. Prepared for the Toronto Home Builders' Association, 1990.

Opportunities and strategies for managing construction site wastes.

Starr Group et al. *New Made to Convert Housing*. Prepared for Canada Mortgage and Housing Corporation, 1988.

Turiel, Isaac. *Indoor Air Quality and Human Health*. Stanford, California: Stanford University Press. 1985.

Summary of health threats found in indoor air, including homes, and what can be done to mitigate impacts. Possible "side effects" of energy efficient housing are discussed.

Van Vliet, D.R. *Urban Design Analysis of Innovative Residential Communities in Scandinavian Countries and Transference to Canadian Urban Planning*. Faculty of Environmental Design, University of Calgary, 1990.

TOOLS

BREEAM (Building Research Establishment Environmental Assessment Method): A method of assessing the environmental implications of buildings at the design stage. The assessment questionnaire is essentially a checklist of characteristics and technologies. Environmental Assessment Scheme, Building Research Establishment, Gatson, Watford, United Kingdom, WD2 7JR.

GRAPHEAT: A graphical energy analysis tool for use at the conceptual stage of design to assist designers to design, and assess thermal comfort in, low-energy, passive-solar housing. Prepared by the Building Engineering Group, Waterloo, Ontario, for the Canada Mortgage and Housing Corporation, Ottawa, 1986.

GRAPHSHADE: A graphical method to establish the effects of shading in the design of low energy passive solar housing. Canada Mortgage and Housing Corporation, 1987.

Hot2000, Canadian Homebuilders' Association. A computer program to assist architects, engineers and builders to design energy efficient, low-rise residential buildings using heat loss/gain and system performance models. Program addresses thermal effectiveness, passive solar heating, operation and performance of heating and cooling systems.



CONTACTS

Re materials options

Royal Architectural Institute of Canada
55 Murray Street, Suite 330
Ottawa, Ontario
K1N 5M3
232-7165

Canada Mortgage and Housing Corporation
Research Division
National Office
682 Montreal road
Ottawa, Ontario
K1A 0P7

Re Waste Management Techniques in Construction

Fonds quebécois de récupération
407 boulevard Saint Laurent, Suite 500
Montreal, Quebec
H2Y 2Y5

Canadian Home Builders' Association
200 Elgin Street Suite 502
Ottawa, Ontario
K2P 1L5
(613) 230-3060

Re Allergies/Sensitivities

Allergy Information Association
Suite 10, 65 Tromley Drive
Etobicoke, Ontario
M9B 5Y7

Re Co-housing

McCamant and Durrett (Architects)
c/o Habitat Press
47 Shattuck Square, Suite 15
Berkeley, California, 94704

Re Rooftop Gardening

Gaia Institute
Cathedral of St. John the Divine
1047 Amsterdam Ave.
New York, New York, 10025
(212) 295-1930

