CMHC's
HEALTHY
HOUSING
DESIGN
COMPETITION

GUIDE
AND
TECHNICAL
REQUIREMENTS

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Introduction

Canada Mortgage and Housing Corporation (CMHC) is sponsoring the Healthy Housing Design Competition to demonstrate to the Canadian public and housing industry that it is possible to design houses for the Canadian climate which are in keeping with the principles of sustainable development, which offer healthy indoor environments, and which remain affordable. The competition is also seen as a means of encouraging innovation which may assist the Canadian construction industry in the development of new products and services for both the domestic and export markets. Following the Competition, CMHC may undertake a demonstration of the winning project(s).

The competition will build upon the research into healthier, more sustainable forms of housing, as undertaken by CMHC and other agencies across Canada; it is partially funded by the Panel for Energy Research and Development (PERD). CMHC's vision of sustainable development includes environmental, economic and social dimensions. A "systems approach" to housing is required, one which takes into account the global environment, the indoor environment, and affordability. The approach will also have to consider the interrelatedness of all the house components.

CMHC recognizes that designing to meet the needs of the occupants and the demands of the economy may sometimes seem to conflict with the goals of environmental protection. The challenge in the design of Healthy Housing is to find an optimum balance — exercising judgment in making difficult trade-offs.

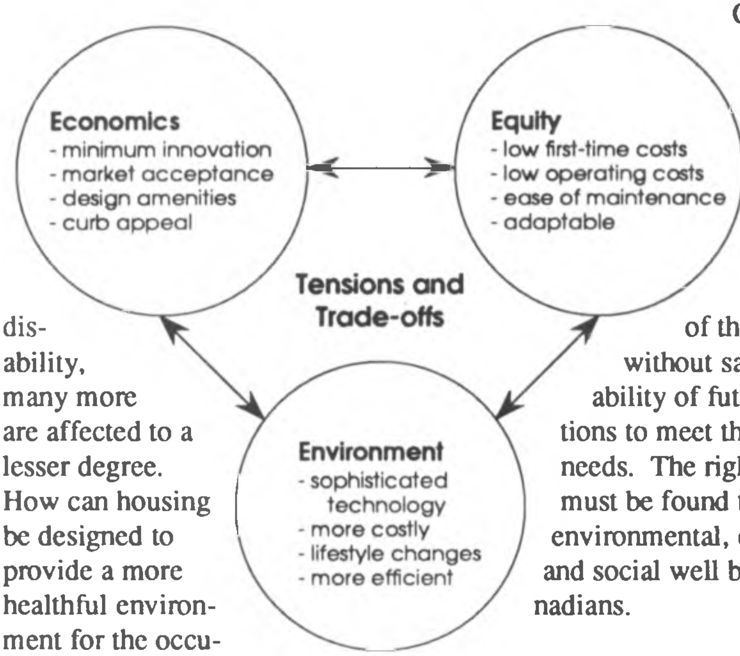
With these considerations in mind, CMHC has structured The Healthy Housing Design Competition in three separate design categories. Submissions may be presented on one of the housing types below:

Suburban Detached: a predominant form of housing in Canada, and one which will continue to play a significant role in years to come:
Older Home Retrofit: a major housing activity which will become increasingly important as existing housing stock is adapted to suit changing household needs.
Urban Infill: a currently popular form of housing which makes efficient use of the existing infrastructure while providing for more urban amenities.

For most Canadians, housing is the largest single expenditure in the monthly budget. When one considers the money and resources needed to build housing and related roads, sewers and other infrastructure, it's clear that housing represents a sizeable investment for society as well as for the individual. And it is a long term investment. Much of our present housing stock will still be in use in 2025 and new housing that we build today could still be in use to 2075.

What will housing be like or, more specifically, what should it be like in 2025 and beyond? That question raises many issues. Firstly, the makeup of families and households is changing, the birthrate is stabilizing and it would appear that population growth will depend on immigration. Who will new housing be built for and what should it be like?

Secondly, concern is increasing over the incidence of environmentally related illnesses. A few individuals are affected to the point of disability, many more are affected to a lesser degree. How can housing be designed to provide a more healthful environment for the occupant?



Finally, housing has major impacts on the environment. Energy, materials, water and land are all consumed in the development and operation of housing.

Much work has been done at CMHC and other agencies to explore the issues of environmental impact and occupant health. Through an active research program CMHC has undertaken extensive work on indoor air quality and has commissioned studies on water conservation, waste management and embodied energy in materials.

CMHC's vision of sustainable development involves meeting the needs of the present without sacrificing the ability of future generations to meet their own needs. The right balances must be found to ensure the environmental, economic and social well being of Canadians.

While CMHC does not intend to direct how such trade-offs are made in the competition, the information in this booklet is intended to identify the issues for both the competition entrant and for the general reader.

How To Use This Guide

Section II of the booklet provides background information on many of the aspects of sustainable housing. The subsections are based on the elements which must be considered and addressed in the development of designs for Healthy Housing, including:

- occupant health;
- energy efficiency;
- resource efficiency;
- environmental responsibility; and
- affordability and economic viability.

A discussion of the issues and background information is provided on each topic together with a description of state-of-the-art developments in housing design and technology.

Section III of the document is designed for competition entrants. The Technical Requirements define the elements which the design team must address in their submissions.

The Issues

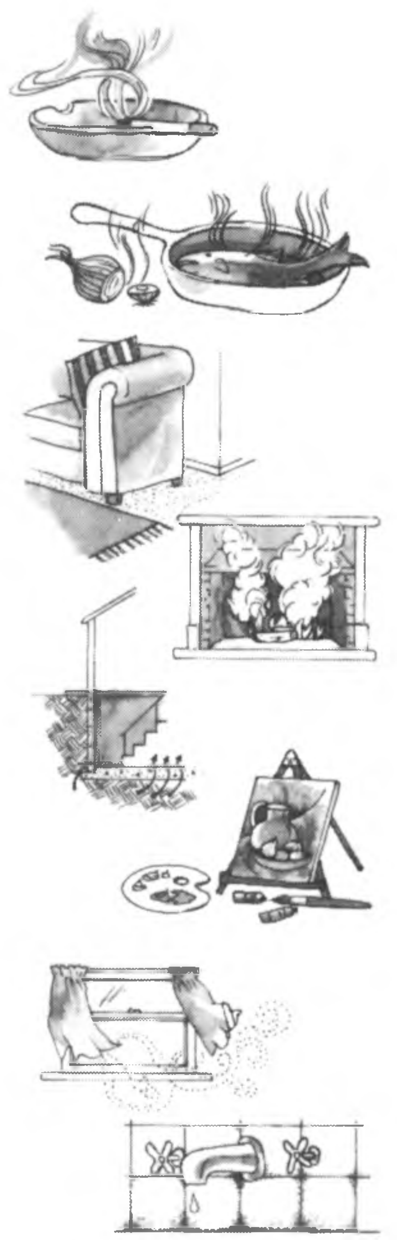
1.0 Occupant Health

Concerns relating to the impact of housing on occupants are being increasingly voiced across the country. Disorders ranging from asthma and allergies to immune system disfunctions and chemical hypersensitivity are being linked to the quality of the indoor air.

To date, the healthfulness of housing has been addressed on an issue by issue basis and from the perspective of isolated disciplines. Medical practitioners attempt to draw linkages with environmental factors, environmental scientists probe the relationships between the built environmental and health, air quality specialists attempt to measure and identify contaminants in the indoor air, and mechanical engineers attempt to design ventilation and air treatment strategies.

Health, itself, is complex and holistic — dependent on hereditary, dietary, emotional, psychological and environmental factors. Considering only the environmental factors, it is evident that health is affected by airborne pollutants and toxins, moulds and mildews, particulates, humidity levels, ions, radioactive elements, light, electromagnetic fields, thermal conditions and sound — to name but a few. An improved understanding of the contaminants and pollutants causing these disorders allows designers and builders to now specify healthier housing — housing which accommodates the desire of homeowners for safer, healthier homes.

In designing a 'Healthy House', a holistic approach to occupant health must be pursued — balancing all factors. The design team must consider indoor air quality, water quality, and background factors including light, noise and electromagnetic radiation.



Sources of indoor air contaminats include: smoking, cooking, formaldehyde, combustion by-products, radon, hobbies, dust and pollen, and mould and mildew

1.1 Indoor Air Quality

As envelope tightness is increased, natural infiltration rates decrease, leading to the potential for greater concentrations in the home of contaminants and pollutants and reduced fresh air for the occupants if remedial strategies are not put into place. A Healthy House will ensure the occupants of good air quality and an adequate supply of fresh air. CMHC's *Housing for the Environmentally Hypersensitive* provides detailed information relating to the sources of common contaminants and strategies which can be employed to improve the indoor air quality — specifically for hypersensitive clients.

While a Healthy House may not need to incorporate all of the strategies required to meet the needs of the hypersensitive, many of the strategies may be employed for the general population. Several guiding principles should be considered when designing healthy housing:

- Reduction of the level of contaminants 'built' into the building;
- Removal of any contaminants at the source of production; and
- Dilution of house air with fresh outside air.

Reduction

The amount of potential contaminants incorporated into standard building materials is significant. Common contaminants causing adverse occupant reactions include:

- volatile organic compounds (from manufactured wood products, carpets, paints, household cleaners, fabrics, inks etc.)
- petroleum (oil and gas vapours)
- moulds, dusts, pollens, animal dander
- woods (natural resins from pine, cedar etc.)

The most frequently reported reactions to these contaminants include tension fatigue, headaches, and eye, ears, nose and throat irritation. In some instances the symptoms are severe enough to interfere with a person's daily activities, life and career.

Materials, construction systems, and mechanical systems should all be evaluated based on characteristics including outgassing, stability under exposure to varied temperatures and moisture levels, cleanliness, maintenance requirements and durability.

Moisture, and its relationship to mould and mildew generation has also been recognized as a contaminant with serious health implications. Construction techniques and mechanical systems which ensure acceptable interior comfort levels, while minimizing health related problems, are a cornerstone of a Healthy House.

Removal

Any combustion by-products resulting from the operation of fossil fuel or wood burning appliances must be vented directly to the exterior, without risk of spillage into the interior environment. Similarly buildings in areas with high radon levels should be designed to remove these gasses before they enter the house.

In addition, homeowners are responsible for a significant component of the production of contaminants, pollutants and irritants in the home, including: moisture production, odour production, and the use of cleaning products, as well as contaminants produced in hobby related activities. A Healthy House will allow the homeowner to remove any contaminants at the source of production.

Dilution

Bringing in fresh exterior air is the third stage in a healthy indoor air quality strategy. In considering ventilation strategies which exchange fresh air for exhaust air, the design team should ensure that incoming air is brought into the home in as clean a manner as possible, in the quantities required for a healthy interior and that the fresh air is thoroughly distributed to all areas of the house.

Filtration, humidity control and effective distribution systems must be considered at the design stage. CSA F326 Residential Ventilation Systems provides guidance on industry accepted ventilation strategies.

The effectiveness of a well designed ventilation system is illustrated in the Advanced House in Brampton. Test results of the house showed formaldehyde levels well below the federal exposure guidelines.

Strategies to address indoor air quality must be balanced with the need to ensure acceptable comfort levels for the house occupants. The distribution of fresh air through the house must be designed to ensure humidity and temperature control within acceptable comfort limits.

Summary

Many of the features in "low-pollution" housing are designed to meet the needs of the chemically hypersensitive and individuals with respiratory problems and allergies. They may also be applicable to housing for the general population. Reduction and removal strategies to consider, include:

- heating systems with minimal spillage of combustion by-products; low temperature heating systems are preferable;
- hard-finish flooring such as ceramic tiles or hardwood; tiles can be laid with cement mortars rather than adhesives; concrete without admixtures, water reduction oils and curing agents, can be used for foundations;
- building materials with no formaldehyde or minimum emission of volatile organic compounds; woods should not be treated with preservatives;
- wall and ceiling finishes that do not require paints (such as plaster), or if painted, non-toxic paints are used;
- draft free building techniques designed to reduce the infiltration of contaminants from the outdoors or from materials in the building envelope;
- good outdoor ambient air quality and location away from heavy traffic, industrial pollution, or power lines is emphasized;
- a ventilation system to bring in fresh air and exhaust stale air from local sources of pollution within the house;
- an air purification system to remove airborne contaminants such as dusts, mould spores, pollens and chemical pollutants;
- a central vacuum system which exhausts to the outside, or other suitable means of removing dust from the home;
- furniture, furnishings, household products selected for minimum emission of volatile chemical contaminants;
- a sufficient amount of natural lighting; and
- a high degree of care during construction to minimize dust and other contaminants.

1.2 Water Quality

Until very recently the availability of pure drinking water was taken for granted in most parts of Canada. Growing awareness of industrial pollution, the limitations of municipal water treatment and outdated infrastructure have called into question the source, the treatment methods and the distribution system presently in use.

Potable water is obtained from surface water (rivers and lakes) or from ground water (wells and springs). Whatever the source, water may be contaminated by bacteria, by chemicals or by metals. Municipal water treatment systems were developed in response to the awareness that diseases such as cholera are spread through contaminated water.

Recent concerns about the quality of drinking water derive more from awareness of industrial and agricultural pollution of surface and ground water supplies. As well, there are some concerns about the health effects of chemicals used in the treatment process, (chlorine in particular) and of the leaching of heavy metals such as lead from the distribution system.

These concerns are reflected in the growing use of bottled water and point-of-use home treatment systems. However, there is a lack of applicable standards to guarantee the quality of either bottled water or the effectiveness of home treatment devices. In comparison, municipal tap water is regulated under the Canadian Water Quality Guidelines, Environment Canada, 1987, and is still the best choice in terms of overall water quality.

Where municipal water supply is not available, treatment methods should be carefully reviewed for effectiveness, servicing requirements and safety.

Home Treatment

Home treatment for removal of bacteria should only be required where the water source is independent of municipally treated supply. Technologies for disinfecting water in the home include:

- chlorination,
- iodination,
- distillation,
- filtration with ceramic filters,
- ultra-violet irradiation, and
- ozonation.

Iodination and chlorination are the only methods which can provide protection against the build-up of micro-organisms in the distribution system. All of the methods require careful attention to operation and maintenance for their safe use.

Other methods are available to remove chemicals and metals. Activated carbon filters have been shown to be effective in removal of trace chemicals. They are sometimes used as part of a two-stage home treatment system to remove chlorine, iodine or ozone residuals introduced during the disinfectant process. Reverse osmosis devices have been shown to be more effective in the removal of metals.

Both treatment devices require periodic changing of a filter or membrane to prevent bacteriological contamination or "break-through" of contaminants. Some home treatment devices will greatly increase water consumption.

1.3 Light, Sound and Radiation

Health scientists and consumers are beginning to voice concerns over the effects of light, noise and electro-magnetic fields on human health and well-being.

Light

The relationship between sunlight, vitamin D and bone growth has been known for generations; children in northern countries are customarily given vitamin D supplements during the winter months. More recently, doctors treating patients for Seasonal Affective Disorder (SAD) have found that symptoms are alleviated by exposing the patient to more sunlight. Specialists involved in workplace design have also found that performance is enhanced if workers have access to daylighting.

Fortunately, the aim of introducing more daylight into the home coincides with energy efficiency. And, the advent of high-performance windows means that designers can plan for generous daylighting — even in rooms with northern exposure — with a lower penalty in thermal performance. The most effective daylighting strategies use windows on two sides of a room to reduce glare. For larger buildings, new technologies such as light pipes or solar assisted light wells are available to bring daylight to the interior of the building. Full spectrum artificial lighting will enhance interior environments.

Noise

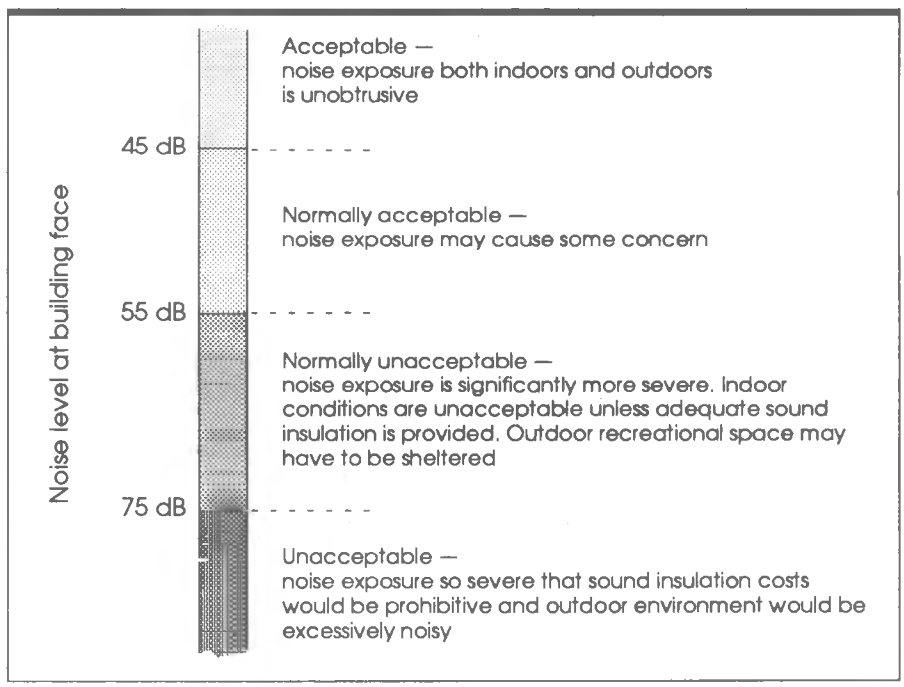
Noise has been referred to as the next pollution issue. Many noises in the urban environment are sufficiently loud to cause hearing damage, not just annoyance.

Building technology is available to reduce noise experienced in the home from both internal and external sources. Thicker envelope construction as for R-2000 homes has the side benefit of reducing noise transmission — isolating the interior from outside noises. Improved detailing and construction practices can reduce transmission within the house and between semi-detached and row-house units.

Air borne sounds can be minimized by sealing any air leakage paths between rooms. Sealing around electrical outlets, plumbing, and penetrations through and under walls will reduce airborne sound transmission.

Sound absorbing materials can be used to isolate a particular noise source such as a hobby room or TV room. Fibrous materials (mineral, glass or cellulose), work effectively to reduce sound inside an enclosure, a wall, or a room. Sound barrier materials (commonly drywall, plywood, concrete or glass), are non-porous and solid, reducing sound energy passage through reflectance. The heavier and thicker the material, the greater the sound reduction.

Plumbing systems, house appliances and fans (exhaust, furnace, heat recovery ventilators, etc.) can all contribute to indoor noise levels. Equipment which vibrates should not be directly affixed to the structure — acoustical isolators can reduce vibration and motor noise. Thoughtful design of floor plans — considering the location of equipment and appliances— and specification of quieter equipment can provide major benefits to the house occupants.



Source: CMHC, Road and Rail Noise: Effects on Housing

Electro-Magnetic Fields

The effect on human health of extremely low frequency electro-magnetic radiation is an issue of growing concern amongst consumer groups, medical researchers and health advocates. Electro-magnetic radiation is part of the total energy spectrum which includes varying wave lengths from high frequency gamma waves through to low frequency radio.

The alternating current that is common to our electrical system, from power lines to appliances, causes both magnetic and electric fields of extremely low frequency (ELF). While both fields drop off rapidly with distance, the electric fields are easily blocked by solid materials — whereas the magnetic fields penetrate substances, including human tissue.

Sources of ELF in the home include nearby high voltage power lines, low voltage distribution lines on the street and in the home, as well as all electrical equipment, appliances, and wiring circuits.

Some researchers contend that electro-magnetic radiation harms the immune system and is linked to cancer. No one knows what a 'safe' level of exposure is but specialists in the field suggest that 'Distance is the Best Defence'. A viewing distance of 4 to 5 feet for television and 3 feet for video display terminals is recommended. Since continued exposure is the greatest concern, beds should be situated away from walls where electricity enters the house, and away from TV's or video terminals. Electric blankets, waterbeds and even electric clocks emit ELF's. ELF's are obviously not produced when appliances are unplugged.

2.0 Energy Efficiency

The greenhouse effect, acid rain, and the depletion of the ozone layer are all caused by the production and consumption of energy, in all its various forms. In Canada, energy consumption in homes represents almost 20% of the country's total energy consumption. And the energy embodied in the materials used to build the homes represents an additional significant input. At our current rate of consumption, Canadians have the dubious distinction of being one of the most wasteful energy-users in the world on a per capita basis.

On average, two thirds of home energy use is consumed by space conditioning — heating and cooling. The operation of lights and appliances accounts for another 17%, while domestic hot water heating accounts for approximately 15%.

Of equal importance, when considering energy use in the residential sector, is the amount of energy consumed in the manufacturing of materials used in the construction of a house.

Reconsidering the manner in which we design, construct and operate houses can result in major energy savings over the lifetime of the house. Those energy savings will result in a reduced demand for increasingly expensive new sources of energy — sources which are also placing a strain on the natural environment, be they new electrical generating capacity or new fossil fuel sources from increasingly remote locations.

Reducing the demand for energy in our houses also increases the viability of renewable energy sources — enhancing the potential for solar space and water heating and allowing for consideration of electrical generation based on renewable sources such as solar powered photovoltaics and wind powered generation.

The following pages look at many of the opportunities available to the design team trying to maximize energy efficiency in housing. Any strategy should be based on reducing the demand for total and peak energy by:

- a more judicious selection of construction materials;
- improving the thermal envelope of the building;
- improving the performance of heating, cooling and climate control systems; and
- minimizing the energy consumed in the operation of lights, appliances, fans and domestic hot water (DHW).

Having reduced the requirements for energy to a low level, alternative supply strategies can then be considered.

2.1 Embodied Energy

Manufacturing Energy Inputs

Recent research has focussed on the energy embodied in the materials used in the house construction process. It has been estimated that the energy embodied in the materials — the amount of energy required to manufacture, transport and install materials used in house construction — represents as much as 30 years worth of operating energy consumption. As this research is refined further to account for local and manufacturer specific processes, designers and builders will be able to make choices relating to house design and material selection which optimize energy use.

A considerable amount of energy is consumed in the fabrication of materials used in a typical house. Large quantities of energy are required to produce everything from glass for windows and glass fibres for insulation through to bricks and ceramics. Major energy savings can be made through the wise choice of building materials. For example, a typical wood frame home has 1/3 the embodied energy of the same house built of steel and concrete.

Material	Energy Intensity*
Concrete (ready-mix, regular weight, 2000 psi)	2742 MJ/m³ (2096 MJ/yd³)
Framing lumber (2 x 4 wall studs)	3264 MJ/m³ (28 MJ per 2 x 4 stud)
Gypsum board (4 x 8 12 mm sheet)	60 MJ/m² (176 MJ per sheet)

* Values shown are based on averages for the Canadian economy using 1984 statistics, and include all the energy required for extraction of raw materials, processing, fabrication, and transportation to site in an urban centre. Values shown *do not* include installation on-site, repair and replacement over the lifetime of the home, or demolition and disposal.

Table: Embodied Energy

Source: CMHC and Sheltair Scientific

The accompanying chart lists typical values for energy consumed in the fabrication of construction materials.

When considering the design of a Healthy House, the design team must evaluate the energy consumed in manufacturing a product in relation to its life expectancy, to the energy saved in house operation and to the replenishment cycle of the material.

Energy intensive materials with long life expectancies may be justified. While many of the insulation materials are energy intensive in their manufacturing, they can be long lasting while dramatically reducing the operating energy needs of the home. As an example, 5.1 GJ more energy would be embodied in a 2x6 (RSI 3.5) wall than in a 2x4 (RSI 2.1) wall. However the energy savings resulting from the upgrade would result in an energy payback of only 2.6 years — and significant net savings over the duration of the building.

CMHC's *Embodied Energy of Building Materials* provides data for determining the energy required to build any form of housing. Also, a software program based on EXCEL is available to assist the designer in determining the least energy intensive construction processes.

Transportation Energy Inputs

Materials should be evaluated based on their availability in the local marketplace.

Transportation of goods is especially energy intensive when considering the huge distances between major urban centres in Canada. Locally extracted and manufactured products require less energy in transportation. Balancing operating energy savings and system performance with transportation energy requirements will represent another of the trade-offs required in a more holistic approach to house design.

Recycled Reused Materials

Because of the energy required in initial processing of materials, the more recycled and reused materials used in construction, the better. Increasingly, building products with recycled materials are being made available. Insulation and underlay fabricated from recycled newsprint and cardboard, drain tiles and carpeting manufactured from recycled plastics, drywall incorporating recycled board stock, and manufactured wood products employing waste wood are currently being marketed. Many other innovations are under development.

Maintenance/ Demolition / Replacement Energy Inputs

The expected useful lifetime of a building product must be taken into consideration. Energy is required not only in the initial manufacturing and installation, but also to maintain, demolish and eventually replace materials.

As an example of the trade-offs and balancing required in considering total energy inputs, consider the selection of cladding systems. While wood sidings may require less energy than other sidings in the manufacturing process and may be locally available, the energy used in the manufacture of paints and stains required over a 40 year life cycle may prove significant. On the other hand, bricks consume a significant amount of energy in both manufacturing and transportation, but are relatively maintenance free and long lasting.

2.2 Building Design Heat Loss

Design heat loss represents the amount of energy required to maintain acceptable indoor temperatures at the building's design temperature. The lower the design heat loss of the building, the lower will be the energy required to heat and cool the building throughout the year.

The design heat loss of a building is a function of the surface to volume ratio of the building, the thermal resistance of the building envelope, and the natural air leakage rate of the building. Design heat loss can be reduced through the following measures:

Minimizing Building Surface Area:

- Design for the lowest possible exterior surface area to floor space ratio.
- Reduce the surface area of the building which is exposed to the exterior temperatures — row or stacked housing reduces the number of exterior walls.

Improved Thermal Resistance:

- Reduce thermal bridging across the building envelope by minimizing excess framing lumber and isolating the foundation from the surrounding soils.
- Install higher insulation levels in foundation and above grade walls and ceilings.
- Install high performance windows (which provide RSI values three times that provided through conventional double glazed windows).

Reducing Natural Air Leakage:

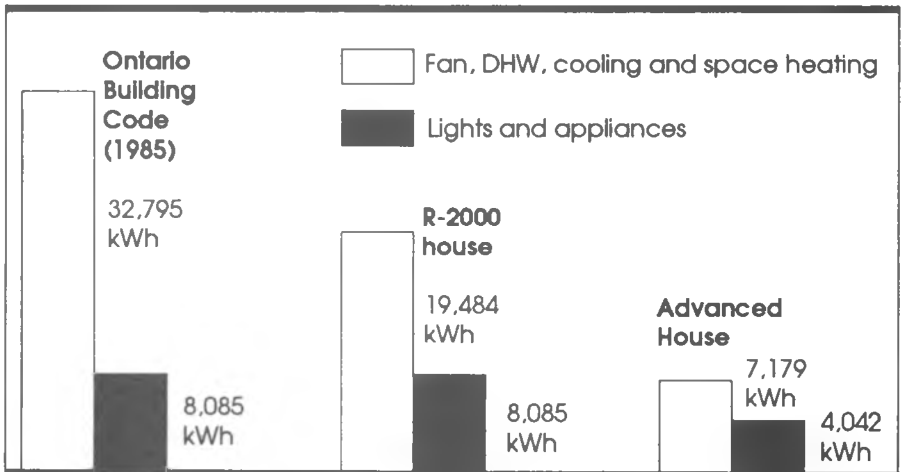
- Employ air tight construction practices.
- Install windows and doors with low infiltration rates.
- Minimize penetrations in the building envelope such as those for fans and electrical fixtures.

Since the mid-1970's, the Canadian residential construction industry has been a leader in the design and construction of energy efficient homes. From the Saskatchewan Conservation house, through the R-2000 Program and continuing in the Advanced House, built in Brampton in 1990, Canadian designers and builders have been on the leading edge of developing designs and construction techniques to maximize the energy efficiency of the thermal envelope.

The chart below compares the design heat loss of a 200m² house built to Ontario Building Code requirements with that required by the R-2000 Program and the Advanced House — all factored as they apply to Toronto.

Modelling Design Heat Loss

A variety of computer software programs have been developed to assist the designer in modelling design heat loss and predicted energy consumption. HOT-2000, ENERPASS, BLAST, and DOE-2 are applicable for Canadian climatic conditions.



Advanced House predicted annual energy consumption, compared with a conventional house and an R-2000 house of the same design

Source: The Advanced House

2.3 Energy for Heating, Cooling and Ventilation

Having reduced the design heat loss of the building envelope, the design team should attempt to maximize the efficiency of the heating, cooling and ventilation equipment specified for the home. As the design heat loss of the envelope has decreased, this has made possible the development of new, smaller and more integrated mechanical systems. Over the last ten years, major advances have been seen in the development of systems designed to replace more inefficient, older technologies.

The accompanying chart shows how performance efficiencies of standard furnace technologies have improved over the years. The higher the efficiency the greater the utilization of the fuel source.

There has been a major trend in heating, cooling and ventilation equipment towards smaller components and more integrated systems — systems which integrate heating (of both space and water), cooling and ventilation functions or some variation thereof.

These integrated systems hold the potential to maximize efficiencies — both in operation and in installation. The Integrated Mechanical System (IMS) installed in the Advanced House in Brampton integrates thermal storage, heat pump technology and heat recovery for an overall reduction in purchased annual energy of more than 50% when compared to conventional systems. Similar efficiencies are being provided by a variety of other systems under development.

Equipment Characteristics	Operating Efficiencies
Standard Gas / oil furnaces pilot / natural draft	55-75%
Mid Efficiency electric. pilot / induced draft	75-85%
High Efficiency condensing	90-95%

Table: Equipment and Operating Efficiencies

As conversion efficiencies improve, the energy consumption of other system components increase in importance. Fan power consumption can be significant. Conventional exhaust fans operate at efficiencies as low as 3%. Circulating fans and fans in balanced ventilation systems can also be major consumers of electricity. Of all fan types available, those with direct current motors operate most efficiently.

Designers should select fans based on a holistic approach — considering installed costs in relation to operating costs.

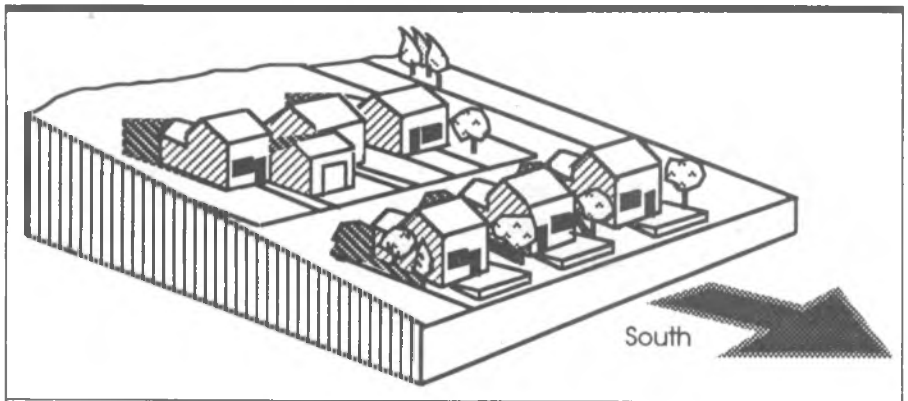
2.4 Renewable Energy Technologies

Renewable energy technologies also offer cost-effective methods to meet space and water heating needs — especially with the reduced demands of the more efficient house. Some recent homes are meeting 100% of their heating requirements with solar!

Passive solar heating can provide much of the heating needs of a relatively airtight structure. This is especially true when considering the performance of new windows on the market. When incorporating Low-E coatings, gas filled units and improved edge construction processes, a historically weak component of the envelope is turned into a net supplier of heat to the home. Conventional RSI 0.3 windows can be replaced by windows with resistance values exceeding RSI 1.4. Passive solar strategies are based on orientation of the building to optimize solar gains, thermal storage materials to reduce temperature fluctuations and distribution systems to move heat throughout the building. Major design considerations should include:

- optimizing south facing glazing for passive solar gains without contributing to overheating;
- maintaining east, west and especially north exposures to a minimum required for aesthetics and daylighting;
- maximizing the glazing to frame ratio, using larger windows in place of several smaller units;
- sizing thermal mass to maintain temperature fluctuations within occupant acceptable ranges; and
- providing for circulation of warmer air to cooler parts of the house.

CMHC's *Passive Solar Designs* elaborates on design strategies to incorporate passive solar heating and *Grapheat* is a manual design tool developed by CMHC for modelling passive solar performance.



Site orientation and adjacent structure shading

Source: CHBA, R-2000 Builders' Manual

Active solar heating has been extensively used throughout Canada for the heating of domestic hot water, and less extensively for space heating.

Active solar heating generally utilizes roof mounted collectors which supply heat to a remote rock or water storage chamber. The storage mechanism can then provide the required heat for domestic hot water or, alternatively, it can heat air being circulated throughout the house.

The reduced space heating load of energy-efficient houses opens up new possibilities such as a solar assisted integrated mechanical systems.

A variety of recently commercialized options, such as air source or ground source (earth energy) heat pump systems also offer improved system efficiency. While their high capital cost must be considered in relation to a reduced heating and cooling load, earth energy systems use electricity three times more efficiently than electric resistance heating. (For a description of EES's, see CMHC's *Earth Energy Systems: A Guide to the Technology).*

Heating with wood and other biomass materials offers another form of renewable energy. Recent advances in the design and manufacturing of wood heating equipment have resulted in more efficient and cleaner combustion.

Designers must balance the desire to employ renewable sources of energy such as wood with the need to reduce outdoor emissions.

2.5 Electrical Consumption and Peak Demand

Through a combination of innovative design, and state-of-the-art equipment, designers can cut the operating energy needs of lighting and appliances by as much as 50% that of conventional housing. For example, the Colorado Minimum Energy House has reduced annual electrical consumption to 2,200 kWh. Any improvements in overall efficiency will also reduce peak demand.

Reductions in peak demand are significant since they directly impact the required capacity of the utility. Minimizing peak demand — the maximum requirement of the house — means the utility requires reduced generating capacity. At the same time peak demand is often provided through coal fired generating plants — those plants which contribute most significantly to the greenhouse effect.

Through the use of control technology, designers can significantly reduce peak demand by shifting some electricity demand from high-use to low-use periods.

Appliances

The chart presents a comparison between the tested energy-consumption of the most energy efficient appliances and their conventional counterparts.

As with all appliances, there are two costs that need to be considered; the purchase price, and the lifetime electricity cost of each unit. Higher efficiency appliances generally come with a higher price tag. However, the cost of running the equipment is relatively low, which means in most cases, and in most parts of the country, the initial cost will pay for itself over the lifetime of the equipment.

Energuide ratings for most conventional appliances are available. Many of the state-of-the art appliances have not been tested to the Energuide standard, but several American and European appliances have greatly enhanced operating performance.

Appliance	Rating (kWh/y)	Usual Range (kWh/y)
Refrigerator • Sun Frost 16 cu. ft. • Rating 20 kWh/m	240	876 - 1980
Dishwasher • AEG Favorit 5251 (2.5 L)	672	1007 - 1382
Range • Thorn 4 burner ceraminc cooktop • Halogen infrared heat source	NA	324 - 444
Oven • AEG B88L double wall convection and conventional heating	348	372 - 432
Clothes Washer • AEG Lavamat – front loading	708	600 - 1536
Clothes Dryer • AEG Lavatherm 620 • 110 L. drum	612	552 - 1200

Ratings for energy-efficient and conventional appliances

Source: The Advanced House

Lights

Lights generally account for about two per cent (1 000 kWh/y) of household electrical energy needs for an all electric house; not a large amount in the scheme of things. With improved design strategies and state-of-the-art lighting technologies, lighting needs can easily be reduced to 250 kWh/y.

Reducing the need for artificial lighting is the first step in reducing lighting energy needs. The provision of daylighting is one reduction strategy — using properly designed windows and skylights, and interior finishes designed to distribute the lighting.

Improved window technologies allow for increased daylighting without the major energy penalties associated with older windows.

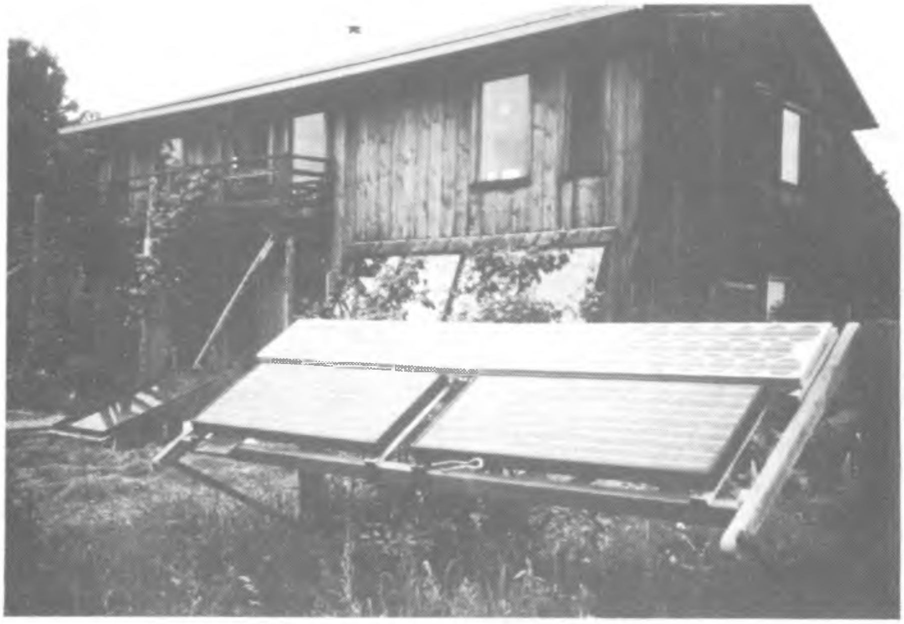
Lighting is divided into general room lighting (ceiling or wall fixtures that provide overall light to an area) and task lighting (lighting used for specific purposes, such as reading lamps). Using general lighting as task lighting can result in an inefficient use of light. Improved design will allow occupants to adjust lighting levels to meet specific room functions. As part of this strategy, more lights can be controlled by individual switches. This allows the occupant to light specific areas of a room independently.

The increased sophistication of lighting controls also offers potential savings through the use of automatic timers and dimmers.

It has long been known that incandescent bulbs are energy liabilities, turning most of the electricity that reaches them into waste heat rather than light. Compact fluorescents use 75 per cent less energy than incandescents, and have a lifespan approximately ten times longer than regular bulbs. In addition, lower watt fluorescents can be used in place of higher watt incandescents.

Renewable Power Sources

Finally, renewable sources of power generation are often associated with autonomous housing — housing which does not demand power from a central grid. Wind power, small scale hydroelectric and photovoltaic generation systems, providing all electricity needs for lighting and appliances have proven viable in many rural locations. For more modest applications, freestanding outdoor lighting units powered by photovoltaic cells and an integral battery are now readily available.



3.0 Resource Efficiency

Housing is a major consumer of Canada's natural resources. The construction and operation of our homes and communities places a real burden on Canada's forests, water, petroleum and land resources.

At virtually every stage of the design and construction process, inefficiencies in the use of materials can be identified — in many cases justified by a perception of Canada's seemingly plentiful natural resources. Yet in each and every case where resources are extracted, processed and manufactured, a burden is placed on the broader environment — and the resource base is diminished.

A more efficient use of resources offers the potential to improve affordability of our housing, decrease energy consumption associated with extraction and processing, and minimize the environmental impact of resource use, from extraction through to disposal.

More efficient designs will also allow for environmental effects to be 'amortized' over a longer period of time. Alternative designs can minimize the need for raw materials extraction — be it forest based, petroleum based or water related resources. And more efficient construction processes can reduce wastage on the site.

Minimizing the environmental impact of housing may require new approaches to community planning, housing design, materials selection, construction techniques and the regulatory approvals process.

3.1 Materials

	Materials Breakdown	Quantity (as built)
1	sand and gravel	50 tonne
2	lumber and timber	41 m3
3	plywood (9 mm)	246 m2
4	plywood (12 mm)	246 m2
5	plywood (15 mm)	562 m2
6	fibreglass batt (89 mm)	149 m2
7	fibreglass batt (152 mm)	249 m2
8	blown mineral fibre (300 mm)	159 m2
9	gypsum board (12 mm)	746 m2
10	paints and related products	112 L
11	glass, plate, sheet	429 kg
12	ready-mix concrete	81 m3
13	sand lime bricks and blocks	116 each
14	bricks and tiles, clay	3818 each
15	steel bars and rods	111 kg
16	plastic pipe fittings and sheet	335 kg
17	felt, carpet cushion	162 m2
18	carpeting and fabric rugs, mats, etc.	162 m2

Table: Summary of building products for a typical 192 m2 house

Source: Sheltair Scientific

Building size and form plays a major role in the amount of resources required in both the construction and operation of a home. Clearly, bigger houses require larger materials input. Reducing material requirements through optimized building size and form can result in many different approaches to housing. Basements, which consume large quantities of resources, may not prove to be justified in some areas. A cube shape can be seen to have a better volume to surface area ratio — resulting in increased interior space in relation to the materials required in the building envelope. The design process must balance efficiency in both size, form and function to result in an efficient, yet marketable, product.

Reduced requirements for construction materials can be achieved in part through the use of material-efficient design and construction detailing. Increased use of modular room layouts and framing patterns might optimize resource use — from the framing materials through to the finished flooring.

An analysis of conventional building practices can identify several examples of overbuilding which have become entrenched in the construction process. Multiple stud corners, doubled top plates, under-spanned floor joists and heavier than required lintels are all conventionally applied detailing and construction practices which incorporate excessive materials. A thorough analysis of conventional construction procedures will identify a host of other opportunities to maximize efficiency in resource use.

Design and construction of the Healthy House will also require an assessment of resource utilization — not solely on the construction site, but the efficiency of resource use at all stages in the extraction, processing and disposal of the product.

Specifying and purchasing materials which are wasteful in their extraction and processing maintains the cycle of inefficiency. In many cases, the designer/builder will be offered two similar products with suitable performance characteristics — one fabricated from raw materials, while the other may incorporate a high percentage of recycled content. Selection of materials and components with a relatively low material input to output ratio in production, and/or a high recycled content enables a reduction in raw materials extraction. Environment Canada's ECOLOGO program provides guidance on materials with a lesser environmental impact.

A 'sustainable' philosophy will also consider the replenishment rate of the various materials being considered for use in the home. While forests in Canada, when well managed, can be seen to be renewable within a lifetime, the same cannot be said for some forest products harvested in tropical forests — which have replenishment cycles of more than 100 years. The replenishment or renewability factor must be taken into account at all phases of the design and materials specification.

3.2 Management of Construction Waste

CMHC is working with the Toronto and British Columbia Home Builders' Associations on the issue of construction waste. As much as 2.5 tonnes of wastes are produced in the construction of typical new housing in Canada. That, and an even higher rate of waste generation incurred in the demolition and renovation of homes, represents a waste of resources and energy, and places an additional burden on landfill capacity.

Waste management on the construction site will be based on four R's: a review of conventional procedures; reduction in the wastes being generated; re-use of materials, and recycling of what has conventionally been seen as waste.

Construction practices can be altered to minimize wastes. Central cutting areas — allowing for easier access to off-cuts — improved site storage procedures designed to minimize water damage and improved inventorying procedures can optimize resource use.

Many materials commonly thrown into a disposal bin can be re-used on site. Off cuts can be employed for blocking and bridging, insulation can be placed into the attic, drywall offcuts can serve as additional thermal mass. Finally when optimum use of materials has been accommodated, leftover materials can be recycled. Throughout the country, recycling programs for construction materials are being implemented. Drywall, cardboard, wood, plastics and asphalt recycling facilities are but a few of the recent initiatives designed to reduce the burden on waste disposal facilities.

The design of Healthy Housing must take into account wastage produced during construction, as well as the ultimate disposal of construction materials as they approach the end of their useful lifetime.

3.3 Water

Canada is a water-rich nation, with 20 per cent of the world's fresh water resources. Yet water is a resource under pressure. To begin with, only 9 per cent of our fresh water reserves are usable. In addition, sixty per cent of river discharge runs north to the arctic, while ninety per cent of the population lives within two hundred miles of the southern border. Finally, demand for potable water has increased seven-fold in the past ninety years, with seventy-five per cent of that increase occurring in the last two decades. (On a per capita basis, Canadians are the second largest users of water in the world, with each Canadian using, on average, 350 litres per day.)

Along with the increase in use has come an increase in the amount of wastewater that needs to be treated and purified. For many municipalities, the cost of providing and expanding sewage treatment and water purification facilities has become prohibitive. For the building community, the consequences have ranged from lower density subdivisions to outright bans on further development.

One of the best ways to reduce the demand for potable water and the production of wastewater is by improving the efficiency of water use. Experience has shown that residential water use can be cut by at least 30 to 50 per cent with no attendant effect on lifestyle. While some of these savings are the result of changes in habit, the majority are the result in changes to water-using hardware.

Indoor Use: Water-Efficient Fixtures and Appliances

An understanding of where water is consumed in the household will give a good indication of how to tackle the problem of reducing its use.

The bathroom accounts for seventy-five per cent of water use in the home. Low-volume toilets require only 6 litres or less per flush (a 35 per cent reduction in household demand). Low-flow showerheads can reduce flow rates by fifty per cent (10 litres per minute as opposed to 20 litres per minute). And low-flow aerators can reduce faucet flow by fifty per cent as well. Note, however, faucet aerators are not recommended in laundry and utility rooms where large volumes of water are needed over a short period of time.

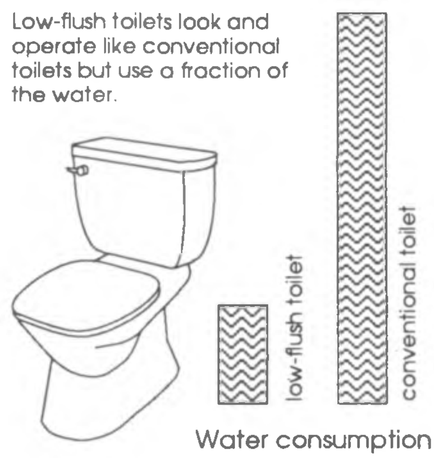
Dishwashers and clothes washers are the two largest water-using appliances. Look for appliances that allow variable load-settings. In general, European appliances use less water than North American appliances.

Current designs of water softening systems, water purifiers and sink garbage disposal systems consume significant quantities of water for their proper operation.

Water use in the home

Source: Environment Canada, Water: No Time to Waste

Low-flush toilets look and operate like conventional toilets but use a fraction of the water.



Toilets and water consumption

Source: The Advanced House

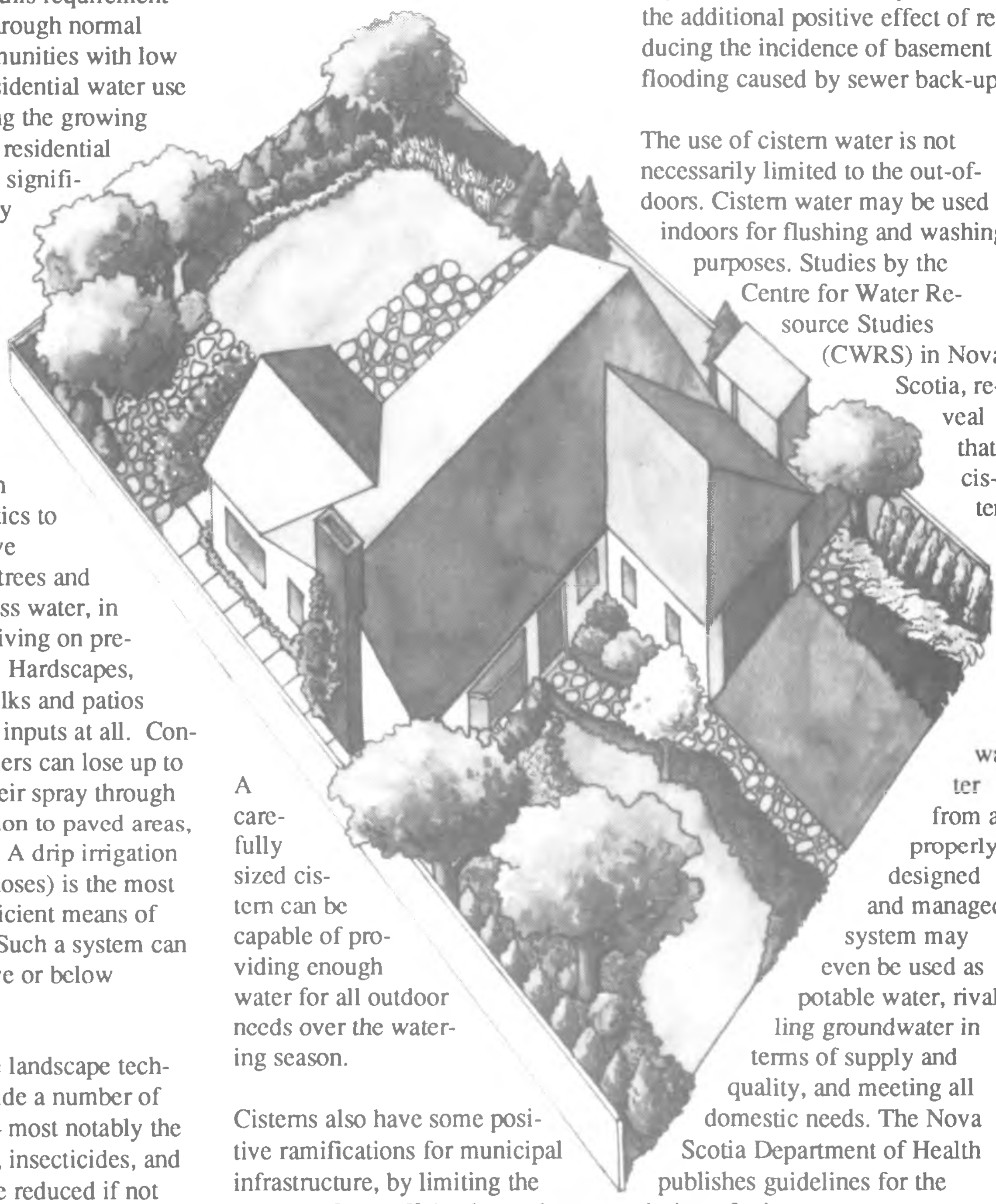
Outdoor Use: Water-Efficient Techniques

A typical subdivision lawn will require more than 200 000 litres of water on an annual basis. In some parts of Canada this requirement cannot be met through normal rainfall. In communities with low precipitation, residential water use can double during the growing season. Outdoor residential water use can be significantly reduced by employing alternative landscape designs.

Limit turf grass areas to what is useful for social and play activities. Switch from thirsty exotics to more hardy native grasses. Native trees and shrubs require less water, in many cases surviving on precipitation alone. Hardscapes, such as stone walks and patios require no water inputs at all. Conventional sprinklers can lose up to 50 per cent of their spray through run-off, application to paved areas, and evaporation. A drip irrigation system (soaker hoses) is the most effective and efficient means of applying water. Such a system can be installed above or below ground.

Employing these landscape techniques will provide a number of other benefits — most notably the use of fertilizers, insecticides, and herbicides can be reduced if not eliminated.

Cisterns are an effective method for capturing and storing rainwater. Cisterns can be as small as a barrel, but are more commonly an underground tank or room in a basement capable of holding large volumes of water.



A carefully sized cistern can be capable of providing enough water for all outdoor needs over the watering season.

Cisterns also have some positive ramifications for municipal infrastructure, by limiting the amount of run-off that has to be appropriately managed. On a typical urban lot, the roof of the house covers one-third of the area. Consequently, with an adequately sized cistern in place, there would be approximately one-third less run-off entering the sewer system. Reducing stress on the sewer system has the additional positive effect of reducing the incidence of basement flooding caused by sewer back-ups.

The use of cistern water is not necessarily limited to the out-of-doors. Cistern water may be used indoors for flushing and washing purposes. Studies by the Centre for Water Resource Studies (CWRS) in Nova Scotia, reveal that cistern water from a properly designed and managed system may even be used as potable water, rivalling groundwater in terms of supply and quality, and meeting all domestic needs. The Nova Scotia Department of Health publishes guidelines for the design of rainwater systems.

3.4 Durability and Longevity

Durable materials and durable housing provide greater mileage out of the initial resources employed in the construction of the house, and allow optimization of the resources required to maintain and repair the building.

Housing which is designed to last — while at the same time being adaptable to changes in lifestyle, technology and occupant patterns — represents an optimal use of resources. The bulk of the resources incorporated into the house are tied up in the structural elements of the building. Structural assemblies with longer life expectancies will maximize the use of resources, and minimize the need to adopt disposal and replacement strategies.

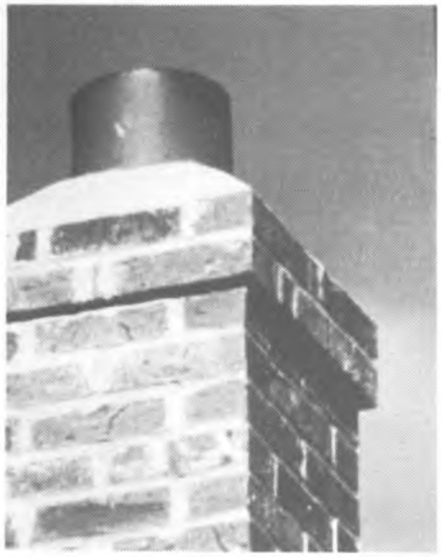
Well designed housing — be it forest product based or masonry — can be found standing many hundreds of years after construction both in Canada and throughout the world. This housing goes through major renovations on a relatively consistent basis (approximately every 30 years), yet the basic structure of the building remains intact. Designs and construction practices which allow for long useful lifetimes demonstrate a sound understanding of building science principles, and represent efficiency in resource use.

Moisture in its various forms (Rain, snow, ice, and interior water vapour) is the major factor causing building deterioration. The continued presence of moisture can result in dry rot, wet rot , and frost and ice damage. More durable housing will be premised on reducing the exposure of the building envelope to moisture — through improved drainage around foundation walls, improved air tightness of the envelope and better weather protection of the exterior building shell.

Buildings must be designed to accommodate ongoing repair, retrofit and redesign of interior spaces. Materials used in the house construction process must reflect the specific design requirements of the local climate. What will work in one part of the country may not represent the most durable design alternative in another region — or even for microclimatic considerations in that region. Using slightly more materials or materials of higher quality can provide a significant improvement in durability.

Designs must also take into account ease of maintenance and repair of the critical components in the building.

Finally, designs should be forgiving — ensuring that a failure of any component of the building does not cause long lasting, irrevocable damage.



4.0 Environmental Responsibility

The word 'ecology' is derived from the Greek word *oikos*, meaning house. If we have learned anything over the past decade, it is that we have to treat the whole planet as our house, and understand that all human activities have an impact on our surroundings and the way in which we live.

We now understand better the impact which our houses have on the broader environment. Ensuring occupant health, energy efficiency and resource conservation in the design and construction of our homes is a cornerstone of environmental responsibility.

We also must consider, and minimize, the environmental impact of the operation of our houses, the manner in which they influence air quality, water quality, the condition of our land, — and even the quality of our communities.

Scientists agree that we are speeding up the rate of climate change through our consumption of fossil fuels. Canadians are amongst the world's highest contributors of greenhouse gasses — averaging 4.5 tonnes/person/year. Through their operation alone houses are responsible for approximately 20% of energy consumption in Canada and a similar percentage of the nation's greenhouse gasses. If the energy consumed in the production of building materials was also considered, housing's responsibility for greenhouse gasses would be even higher.

Canada's relatively vast supplies of fresh water are becoming polluted at an alarming rate. Houses contribute significantly to the deterioration of our streams, lakes and ponds through disposal of hazardous materials into the sewage system and through leaching of outdoor household chemicals into the ground water. And many municipalities are finding it increasingly difficult and expensive to keep up with the growing requirements for fresh water and sewage treatment facilities.

Landfill sites across Canada are reaching capacity, and more and more concerns are being voiced about the toxic 'soups' within these sites. The disposal of toxic materials into landfills can result in lands being contaminated for generations to come.

Conventional construction practices result in the disposal of a significant amount of toxic and hazardous materials. Paint, solvents, caulkings, treated wood offcuts and a host of other contaminants conventionally find their way to our dumpsites — polluting the land and leaching into ground water.

Urbanization is consuming land at an increasing rate across Canada — at a rate in excess of population growth. Between 1966 and 1976, a 1% growth in population was associated with a 1.5% increase of land for urban uses — in most cases at the expense of agricultural lands.

Environmental responsibility means doing more with less — optimizing our use of precious land resources and minimizing our draw on a fixed commodity.

4.1 Emissions and Combustion By-Products

Global warming is primarily influenced by the production of carbon dioxide, which is a by-product of the combustion of carbon based fuels (coal, oil, natural gas and wood). The more energy consumed in the home, the greater the contribution of green-house gasses. Reducing the building's demand for heating, cooling and electricity must be seen as the first strategy in reducing the emission of greenhouse gasses.

Conserving energy will also reduce the production of other fuel-related emissions such as particulates, nitrous oxides and sulphur dioxide, which contribute to outdoor air pollution.

Having minimized energy requirements, the Healthy House would incorporate cleaner burning equipment — equipment which minimizes the emissions of combustion by-products including CO_2, and sulphur and nitrous oxides. Higher efficiency furnaces, and improved wood burning equipment can dramatically reduce emissions. Renewable energy sources such as solar heating are considerably more benign in their operation. Even high efficiency heat pump applications can result in a significant reduction in CO_2 production at the generating plant. Residential wood stoves currently under development show a 90% reduction in emissions when compared with conventional technologies.

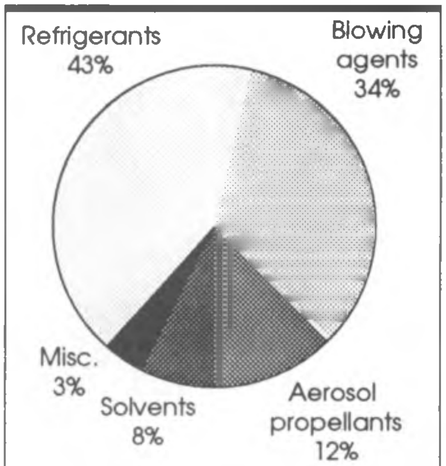
Landscaping for CO_2 absorption can be another component of Healthy Housing. To absorb the amount of CO_2 produced by a 500MW coal generating station, more than 670,000 hectares of forest would need to be planted in Southern Ontario — as much as 4 times more forest in less productive regions of the country.

Refraining from cutting down forests and planting new trees in subdivisions can represent a step in the right direction.

Sector	End-use	Efficiency potential (%)	Contribution to C02 emissions (%)
Residential	space heating and cooling	53%	20%
	appliances	30%	2%
Commercial	space conditioning	53%	11%
	electricity specific	48%	1%

Potential CO2 reduction in Canada from energy efficiency improvements

Source: House of Commons Standing Committee on the Environment



Use of CFC's in Canada (1987)

Ozone depletion is another concern. The earth's atmospheric ozone layer filters out harmful ultra- violet (UV) radiation from the sun. Two families of chemicals, chlorofluorocarbons (CFC's) and halons, deplete the earth's atmospheric ozone layer. Resulting increases in UV exposure will have serious effects on human health and agricultural productivity.

Some materials and equipment commonly used in housing contain CFC's or use them in the manufacturing process. Most refrigerators, freezers and air conditioning units use the CFC freon™ as the heat transfer fluid. Some extruded polystyrene insulation and other products use CFC based blowing agents in the manufacturing process.

Following an international protocol and federal and provincial guidelines, manufacturers are moving to replace "hard" CFC's with less polluting "soft" CFC alternatives or to phase out CFC use entirely.

4.2 Waste Water and Sewage

Minimizing waste water and sewage is a simple matter — the less water that enters the house, the less water that needs to exit the house and undergo purification. Water conserving hardware solutions were discussed in Section 3. Typical residential water use can be easily reduced by up to fifty per cent. But that still leaves a significant amount of waste water in need of treatment. This section looks at ways of reducing the burden placed on treatment facilities.

The greatest residential water use is in the bathroom, in particular the toilet. Treating this waste water is an expensive, resource consuming process. Nor is it necessarily all that effective. (One per cent of raw sewage entering sewage lines leaks into the surrounding soil and eventually into ground or surface water. Also, during heavy rains when plant capacity is breached, raw sewage can be released into surrounding waterways).

The most obvious solution is on-site treatment and the use of septic tank systems. Septic systems, however, do not come without a few drawbacks. First, not all soils are suitable for septic tanks. In heavily populated areas, the land would not be able to properly filter all of the wastes. And they require regular maintenance to avoid clogging of the drain field. However, under the right circumstances, they are a viable options.

Other options include biological toilets — toilets which break-down wastes on-site through the action of enzymes and bacteria, allowing the waste material to be recycled. These toilets can work on both aerobic and anaerobic principles.

Plumbing systems can be designed to separate grey water (water which contains no sewage) from black water (water which contains sewage). The water that drains from bathroom basins, tubs, showers, and laundry rooms is the best source for greywater. Water from the kitchen is also considered grey water, but the fats, oils and greases from dishwashing makes kitchen water hard to filter, and a likely breeding ground for disease.

If greywater is to be recycled, there will need to be significant adjustments made to standard plumbing systems in order to capture the water and transport it to its secondary use. In addition, greywater for re-use in certain areas, such as gardens, may have to undergo some form of pre-treatment. Some new water-efficient plumbing systems include waste water treatment and recycling systems.

The herbicides, fungicides and insecticides applied to residential lawns and gardens is carried with run-off into the water table or fresh water lakes and streams. Application of the low maintenance gardening techniques discussed in Section 3 will help to reduce water consumption. Use of organic gardening techniques and hardy local varieties will make it possible to avoid using harmful chemicals on the lawn or garden.

4.3 Community Planning and Site Planning Issues

Over sixty per cent of Canada's housing stock is made up of single family, detached dwelling units — the least dense of housing options and the most consumptive in terms of land, energy and even water.

Sprawling development patterns not only require large tracts of land for housing, but for the required roads which this auto-oriented form of development entails. On average, residential land consumes over 50 per cent of the total area of typical Canadian cities, — more than 70 per cent when associated roads are considered. At the same time, sprawling developments place greater demands on the urban infrastructure in the form of roads, water and sewer systems, transit and schools.

The suburban development pattern is also more energy intensive, in both construction and operation.

Detached houses consume anywhere from 15 to 67 per cent more energy than other common ground-oriented housing options, and they accommodate some 60 per cent less people per net hectare then row-houses. Dispersed communities have resulted in an over dependence on the automobile; 77 per cent of Canadian households own one or more cars and 73 per cent of journeys to work are made by car. Dependence on the automobile as a prime means of transportation results in greater energy consumption for transportation and increased greenhouse gas emissions. Development patterns have a significant impact on the surrounding environment of both the immediate and the global community. Opportunities for mitigating these impacts are available at two levels;

1. The City or Community Planning Level with its emphasis on transportation, infrastructure and community energy systems; and
2. The Site Planning Level with its emphasis on house-specific, energy, land and water-efficiency issues.

Community Planning Issues

While planning for sustainable communities is beyond the scope of the design of an individual house, a Healthy House design should consider emerging planning issues that will shape the communities of the future. These include density and land use mix.

Density: Housing Intensification as it relates to;

- reducing both the frequency and distance of travel by private automobile;
- enhancing the opportunities for public transportation;
- making better use of existing infrastructure, including linear infrastructure (sewers, roads, etc.) and community infrastructure (schools, fire, police, etc.);
- relieving presssure on otherwise renewable land resources; and
- the provision of more affordable and varied house forms that respond to changing demands and needs.

Land Use Mix as it relates to;

- reducing both the frequency and distance of travel by private automobile;
- community self-sufficiency and economic vitality; and
- enhancing the opportunities for cogeneration and district heating.

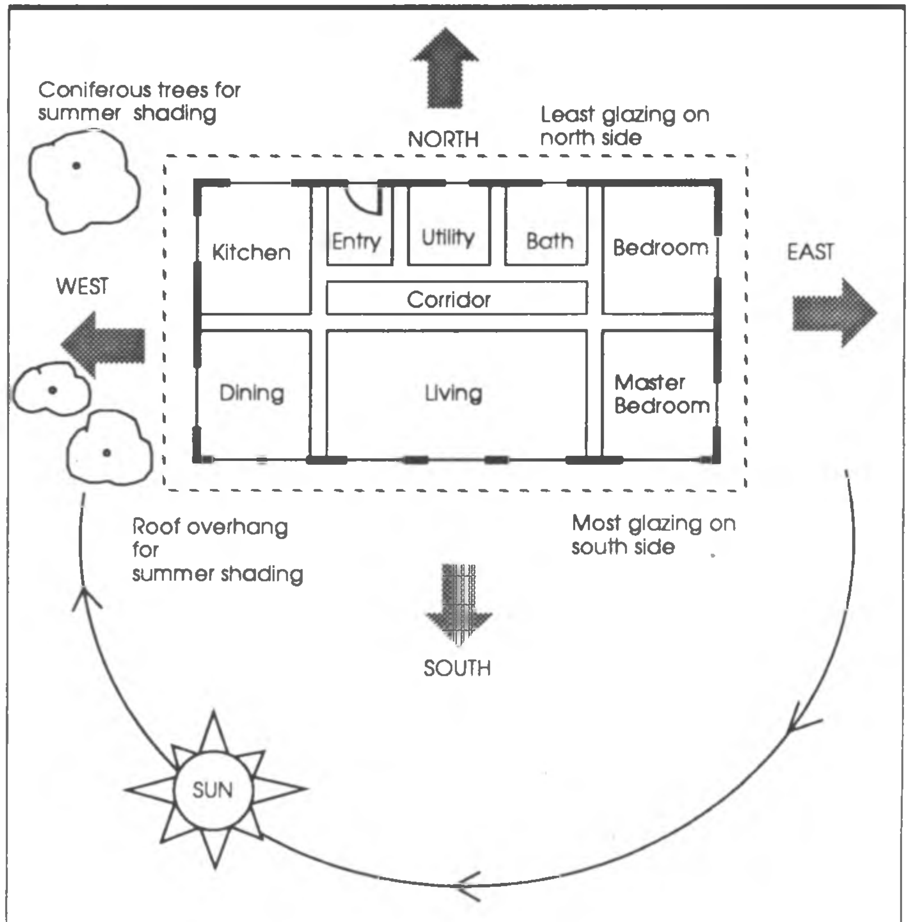
Site Planning Issues

The site plan determines how the house interacts with the surrounding community and environment. Careful site planning can contribute to the efficiency of the individual house, minimize the impact of the house on the surrounding environment and contribute to a 'healthy' social environment. Site planning issues include siting, orientation and landscaping.

Siting as it relates to;
- more efficient us of land;
- the creation of desirable micro-climates; and
- the creation of friendly street-scapes, workable open spaces, etc.

Orientation with a view to;
- maximizing solar exposure.

Landscaping with a view to;
- maximizing winter wind buffering and summer shading;
- planting species that do not require excessive amounts of water; and
- minimizing the use of pesticides and herbicides.



Landscaping considerations

Source: CHBA Builders' Manual

4.4 Hazardous Materials: Landfill and Disposal

Reducing the burden which we place on landfill capacity must be viewed from two perspectives. First, as discussed in Section 3, we must reduce the volumes of wastes being produced to extend the useful lifetime of the facilities. Secondly, we must reduce the negative affects of the disposal of toxic materials on the land, air and surrounding ground water. The design and construction of the Healthy House will reduce construction waste, reduce toxic materials destined for landfill and facilitate improved waste management procedures on the part of the homeowners.

Minimizing the contamination of our landfill sites starts with the selection of materials to be used in the construction of our houses. A Healthy House will limit its use of toxic products — both to ensure contaminant-free interior conditions, and to minimize the longer term problems of disposal of residues and containers. Common contaminants in the construction process include: paints and stains, solvents, caulking, foams and plastics, treated woods, synthetics, and asphalt based materials. Of equal importance, the demolition and renovation of existing buildings also generates toxic materials. In both new construction and renovation related activities, materials considered 'hazardous wastes' should be treated and disposed of accordingly.

The first strategy which should be employed involves reducing the use of any toxic materials in the construction process. Non-toxic, or lesser toxic products, are available as a replacement for many of the problem materials. Environment Canada's ECOLOGO Program identifies several products used in the construction process which have minimal environmental impact.

When hazardous materials are used in the construction process, they should be carefully monitored, to ensure adequate safety in storage and disposal. Hazardous waste disposal facilities are located in most urban areas and, with their improved technologies they represent a better location for the eventual disposal of any toxic materials.

The design of the Healthy House can also influence consumer habits relating to the proper management of household wastes. Household waste management recycling programs have been implemented throughout Canada. Recycling of paper, glass, and metals is currently widespread, and more ambitious programs designed to recycle plastics, boxboard and kitchen wastes are under development. The design of the kitchen and garbage disposal systems in the Healthy House should facilitate responsible waste management on the part of the homeowner. Kitchen designs should accommodate space for returnables, recyclables, and compost. A secure location for storage of household hazardous wastes should be provided outside of the house.

5.0 Affordability and Economic Viability

Charlie: CHBA/CMHC demonstration home

Credit also: Hamilton and District Home Builders' Association

As the Brundtland Commission report, *'Our Common Future'* pointed out, issues of economy and environment are inextricably linked. For Healthy Housing to be widely adopted it must be economically viable as well as environmentally responsible. Affordability is a factor which CMHC regards as an essential aspect of sustainable housing. This section of the Guide will explore four issues related to the economic side of Healthy Housing; affordability, adaptability, viability for the construction industry, and marketability.

5.1 Affordability

Appropriate Housing

Fortunately many responses to environmental concerns also help to make housing more affordable for the individual. Reducing the lot size directly affects the land component of housing affordability. As well, reducing the unit size, creating multi-purpose spaces and optimizing construction details can all result in more efficient use of materials and natural resources, hence lowering costs. In a recent study for CMHC, consumers indicated that they are willing to reduce floor space by as much as 15 percent. In order to provide a saleable product, these measures must be accomplished through the application of design principles which provide for pleasant interior spaces and amenities.

Other strategies for 'appropriate' housing reduce first time costs by eliminating features such as a garage or basement. Others postpone completion costs to a later date; basements and attics can be finished later by a contractor or the homeowner. In some cases, finishing work such as painting can also be left to the homeowner.

First Time Costs and Operating Costs

To the occupant, affordability can be translated as reasonable up front costs and manageable operating costs. In some cases, changes to housing to reduce the environmental impact add to the initial cost while reducing the operating costs. For example, when energy efficiency improvements became desirable in the nineteen seventies, increased investment in the building envelope and mechanical systems were offset by lower operating costs for energy.

First time and operating costs apply to the environment as well as to the individual. The materials and equipment in a house represent an environmental cost in terms of resource extraction and manufacturing. By selecting a longer design lifetime for a building, the environmental costs of the house can be amortized over a longer period of time, resulting in a lower environmental impact for the total occupancy. The environmental impact (and ultimately the cost to society) can also be reduced by making the house more efficient in its operation, e.g., water conserving fixtures not only reduce the load on the municipal infrastructure but also decrease the toxic loading of the water basin. A longer design lifetime also makes it possible for the occupant to amortize the incremental costs associated with greater efficiency, over a longer period.

Until very recently, affordability in housing referred only to first time costs and operating costs for the occupant. A growing awareness of the environmental and societal impacts of housing has broadened the discussion of affordability and is beginning to change the way housing is viewed. A central question in this discussion is, what are the societal and environmental costs of housing? Another is, who is going to pay for the hidden costs or externalities of housing?

Recent Demonstrations

Some of these features and other innovative approaches to affordability are demonstrated in two recent projects: The Grow Home and the Charlie House. The Grow Home was a project of McGill University designed to demonstrate an affordable home for the first-time buyer. The Charlie House was developed by the Canadian Home Builders' Association and CMHC to demonstrate energy efficiency and adaptability. Both homes make use of a smaller lot size and unit size and the Charlie House was built to R-2000 standards of energy efficiency.

Response to these projects has been enthusiastic on the part of the housing industry and consumers, but attempts to develop the homes commercially have met with mixed success. The experience of the Grow Home and Charlie House have underlined some of the social and institutional barriers to the development of more affordable housing, specifically, zoning regulations and community response. Through the "Affordability and Choice Today" program (A.C.T.), CMHC in cooperation with CHBA, CHRA and FCM is hoping to encourage municipal regulatory reform that will remove barriers to innovative approaches to housing.

5.2 Viability for the Construction Industry

Is it Suitable in the Context of the Canadian Housing Industry?

The rate of take up of new technology in the building sector is relatively slow, making investment decisions on new technology difficult. In Canada, this is accentuated by the diverse nature of the residential housing industry. Seventy percent of Canada's 9,000 home builders produce five or fewer houses per year and their efforts are augmented by some 50,000 trade contractors. Technology transfer is a major challenge in the housing sector.

The closer a new technology is to existing practice, the sooner it will be widely adopted. However, there is a downside to this approach. Incremental changes don't allow for a fundamental reassessment of technology and practice. Forcing designs to be applicable in the short term could stifle creative approaches which involve more effort but which also could result in greater environmental responsibility and economic gain in the long run.

Beyond the issue of technological change, housing designs must be buildable from a practical point of view. Straightforward designs which incorporate ease of assembly will be more affordable and more widely adopted even if they include new technology.

Is it Applicable to Retrofit Projects?

The majority of housing units that will be available in the year 2025 have already been built. Renovating the existing housing stock to make it more suitable to the needs of changing households and the environment will be a major activity of the housing industry into the twenty-first century. Innovative designs, methods and products that are developed for new housing will have limited impact on housing affordability and on environmental responsibility unless they are also suitable for retrofit applications.

The Grow Home

Source: McGill University School of Architecture Affordable Homes Program

Does it Provide Opportunities for Canadian Technology?

Recent studies have shown that countries with the highest environmental standards are able to benefit economically through improved efficiency and by exporting the technology which they developed to meet their own requirements. (For example, Japan and (West) Germany use far less water and energy per capita than Canada.) Canada is an acknowledged world leader in the development of cold climate housing technology and is continuing its efforts to export this technology. Further, the wood-frame method which Canadians have developed to a high degree of energy efficiency represents an efficient use of resources. It will be important for Canada to focus on the development of housing products and information technologies with export potential, especially those that have a higher value-added content and involve more efficient resource use. These may be specific products or information technology such as the HOT 2000 software or licensing of the R-2000 technology to the Japan 2 X 4 Association.

5.3 Adaptability

The object of housing is not to consume resources, but to provide shelter for people. Finding a good match between the population and the housing stock makes more efficient use of the environmental and economic investment in the housing, and the attendant infrastructure and contributes to greater energy efficiency per capita from the operation of the house.

However, this is easier said than done. There is a relatively long lead time to develop new housing. The housing industry can be slow to respond to demographic trends. And, once built, even present day housing stock, let alone more durable models, will last for generations — through several demographic cycles. For these reasons, it is important that new housing be designed to accommodate several changes of occupancy over its lifetime.

Studies show that the majority of houses which will be available in 2025 have already been built.This information suggests that much of the demand for new housing units could be met more efficiently by retrofit of existing housing stock. Such initiatives would make best use of the investment in both the housing and the infrastructure of existing residential neighbourhoods.

Examples of Adaptable Housing

Historically, Canada has developed some urban housing forms such as the two or three storey gable-front house that can be easily adapted to changing occupancies. Urban neighbourhoods that have had the advantage of adaptable housing stock, appropriate ownership structure *and* appropriate zoning have been able to absorb major demographic changes with relatively little help from the larger society.

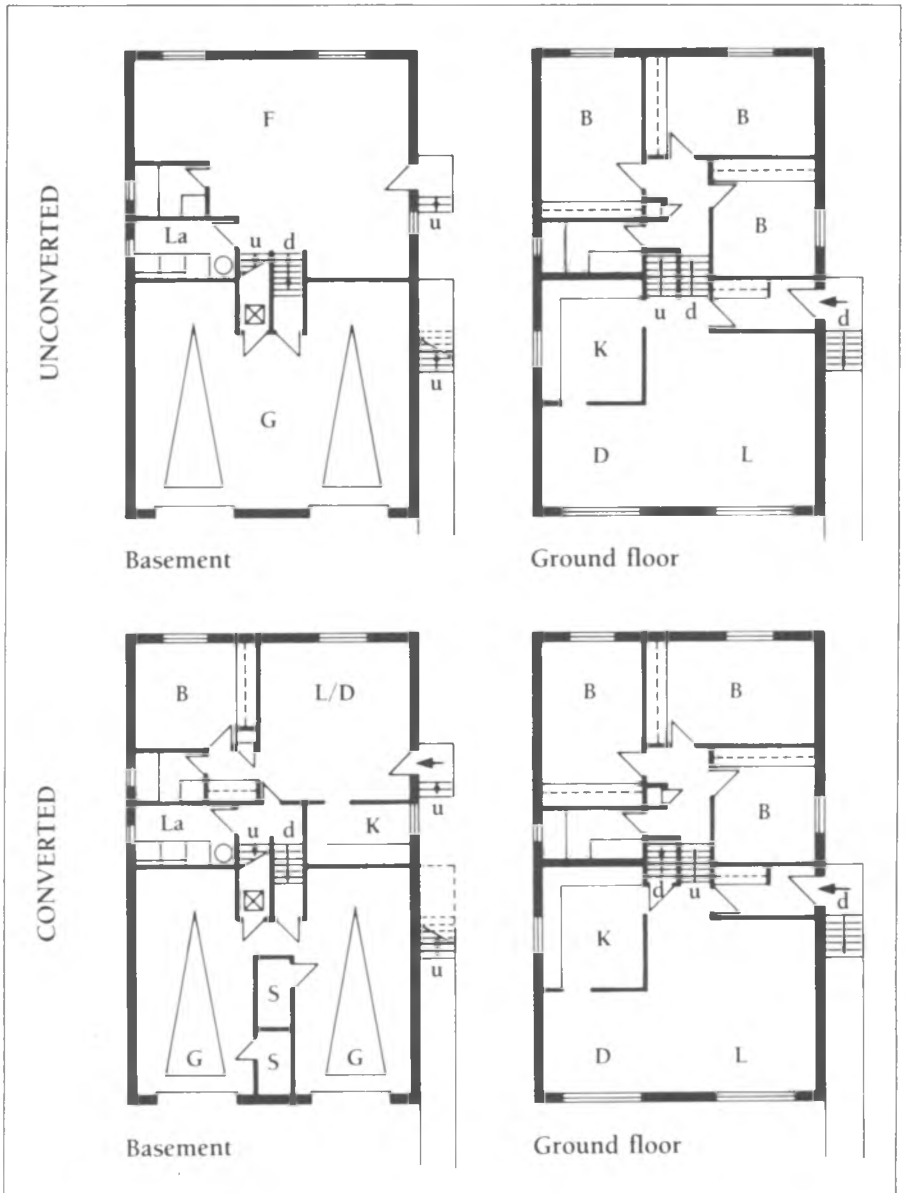
More recent housing forms such as the suburban bungalow are inherently less adaptable and zoning in suburban neighbourhoods is not generally supportive of measures for adaptability such as accessory apartments. However, the use of illegal basement apartments in some suburban areas and the formation of new households of unrelated adults shows that individuals are attempting to make the suburban form more adaptable to present needs. Where this is occurring, factors such as fire hazards and basement flooding need to be addressed.

The Grow Home and the Charlie House are two examples of houses that are designed to adapt to change. The Grow Home approach is to build a building shell with minimal interior fittings and a master bedroom and adjacent study or nursery on the second floor. As family needs require, and resources permit, the home can be expanded by partitioning the bedroom, or finishing the basement.

The Charlie House is 'made-to-convert' between a single family home and a duplex. As family needs and resources permit, the owner/occupant can remove partitions and occupy both the first and the second floor, then contract again to a single floor apartment with an accessory apartment above.

Whether accessory apartments are incorporated intentionally, as with the Charlie House, or despite zoning regulations, as with suburban basement apartments, it is generally recognized that they will continue to play a major role in high demand areas because of their affordability and their ability to respond quickly to changing demographics.

Garden Suites and attic conversions represent other approaches to adaptability. Garden Suites consist of a small free-standing dwelling designed to make use of a large suburban lot rather than alter the original dwelling. These and other options in convertible housing are discussed in CMHC's publication *New Made to Convert Housing*. Options for expanding living space into the attic are discussed in CMHC's Research Report '*Reclaiming the Attic*'.



Back-split house with basement unit

Source: CMHC, New Made-To-Convert Housing

5.4 Marketability

Marketing new products requires an understanding of the demand for innovation. In the Canadian residential sector, the housing industry is conservative; builders tend to follow the market. Studies in market theory have indicated that approximately 13 percent of the population can be categorized as 'early adopters'. The early adopters have a significant influence on the adoption of innovation in Canadian housing. A recent study of early adopters for CMHC, *'Consumer Housing Choices and the Environment'*, revealed that they:

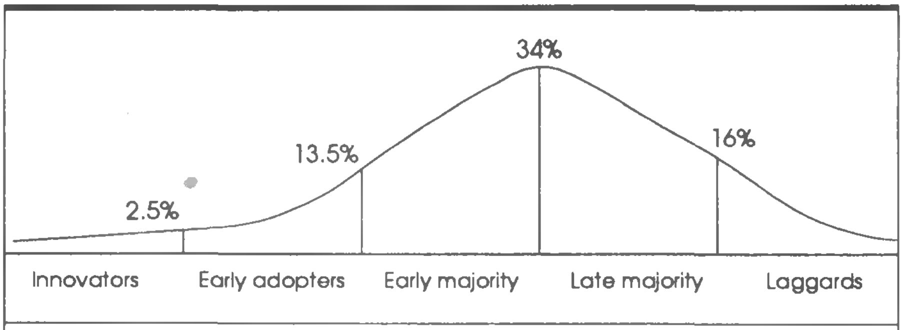
- recognize how their homes affect the environment; and
- do not see today's marketplace offering the type of housing options they expect to see in the future.

When given a range of option packages for new homes, *more than two thirds of the participants selected options with the most significant environmental benefits.*

The study also revealed that, for an environmental house to be successful, it must satisfy other criteria such as: quality of construction, curb-appeal, and lifestyle amenity needs. Specific 'design' requirements are influenced by housing forms traditional to the region, by the immediate context of the home, e.g., downtown or suburban neighbourhood, and the lifestyle needs of the occupants. Some design considerations that will have to be taken into account include, entry access, privacy between and within units, access to private outdoor space, functional and pleasant living spaces, and relationship of the house to vehicle access. A key design challenge will be the extent to which technical innovations are incorporated into the design 'vision' of the house.

Experience has shown that for innovative housing forms to be acceptable, they must be within the bounds of what is commonly defined as home. A case in point is found in two experimental Canadian houses; the Ark and the Saskatchewan Conservation House. The Ark was an experimental self-contained eco-house on Prince Edward Island. As a housing form, it required fundamental changes in household structure and lifestyle as well as new technologies in construction and operation. In contrast, the Conservation House responded to predominant family structures and lifestyles. The Ark remained an interesting experiment while the Conservation House became the model for the R-2000 Home and was replicated across the country.

Experience has also shown that it's not enough for new housing forms to be acceptable to the individual; they must be acceptable to the community as well. Attempts to build the Charlie House, the Grow Home and other innovative forms of housing have met with difficulty from community and neighbourhood associations concerned with zoning by-laws and property values. Careful attention to design values that harmonize with the local community and that are sensitive to site planning issues will help to smooth the way to community acceptance of new housing forms.



Adopter Categories

Source: Energy Pathways Inc., Consumer Housing Choices and the Environment

Technical Requirements
Overview

All submissions will be evaluated on their technical merit — evaluating the manner in which the project team has addressed the technical aspects of the design of a Healthy House. The design submissions will be evaluated for the comprehensiveness of their approach — how the project team has integrated and balanced the different elements and components of the Healthy House.

The evaluation will be performed in a three stage process:

1. Quantitative Analysis: An evaluation of items such as operating energy or water consumption which can be modelled and evaluated quantitatively — based on information provided by the proponent,
2. Qualitative Analysis: An evaluation of items such as materials durability and toxicity or the innovative use of resources which will be rated qualitatively.
3. Challenge Questions: Submissions will be evaluated based on responses to a series of challenge questions posed by the Competition.

Within the scope of the Review, submissions will be considered under the following general headings:

1. Occupant Health and Safety;
2. Energy Efficiency;
3. Efficient Use of Resources;
4. Environmental Responsibility; and
5. Affordability and Economic Viability.

As a guide to the project teams, each of the major categories and sub-categories has been given one of three ratings — Essential (E); Important (I); or Desirable(D). These ratings reflect the importance of the particular subject with respect to CMHC's Healthy Housing Design Competition.

Working with the best information that is available today the competition has been structured to place 'Essential' emphasis on areas where high performance standards have already been established in the field. A 'Desirable' rating for other items does not indicate that the issue is unimportant. It may reflect the fact that the item is dealt with adequately under existing codes and practice, or that at present there is insufficient information available to place emphasis on the topic, or that the topic relates to broader issues that are outside the scope of this competition. The relative weighting of the issues is shown below.

This competition represents just one step in the development of sustainable housing. Extensive building science research and many demonstration projects laid the groundwork. Further demonstration projects and full implementation of Healthy Housing principles will be a major activity of the Canadian housing industry for some years to come.

1. Occupant Health	
1.1 Air Quality: source reduction	E
Air Quality: ventilation	E
1.2 Water Quality	D
1.3 Light, Noise and Radiation	D
2. Energy Efficiency	
2.1 Embodied Energy	I
2.2 Design Heat Loss, (Building Envelope)	E
2.3 Energy for Heating, Cooling and Ventilation	E
2.4 Renewable Energy Sources	I
2.5 Electrical Consumption and Peak Demand	I
3. Resource Efficiency	
3.1 Materials	E
3.2 Management of Construction Waste	D
3.3 Water Conservation	E
3.4 Durability/Longevity	I
4. Environmental Responsibility	
4.1 Emissions and Combustion By Products	E
4.2 Waste Water and Sewage	D
4.3 Community Issues	D
Site Planning Issues	I
4.4 Hazardous Materials: Landfill and Disposal	I
5. Affordability and Economic Viability	
5.1 Affordablity	E
5.2 Viability for the Construction Industry	I
5.3 Adaptability	D
5.4 Marketability	I

1. Occupant Health and Safety

1.1 Technical Criteria

Submissions must stipulate the expected occupancy of the building;

Submissions will be evaluated on the manner in which they have addressed the following issues relating to the indoor environment, occupant health and safety:

- Air Quality (source control and ventilation systems)
- Water Quality (source and treatment)
- Light (natural daylighting, spectrum)
- Noise (exterior and interior sound control strategies)
- Electro-magnetic radiation (production and control strategies)

1.2 Challenge Questions

1. How does the house address the psychological, health and safety needs of the occupants?

2. How does the design balance the trend to more sophisticated systems for air and water quality with the need for ease of maintenance and operation and occupant safety?

2. Energy Efficiency

2.1 Technical Criteria

Submissions **must** provide detailed performance characteristics of the project, including;

- The design heat load of the building and the predicted annual operating costs for Space Heating, Cooling, Ventilation and Domestic hot water based on local climatic conditions.
  (Submissions must be modelled using HOT-2000. If designs involve special modelling requirements beyond the capability of HOT 2000, these should be discussed with CMHC.)
- The peak electrical consumption, as well as the predicted annual operating costs for lighting and appliances.
  (Peak load is calculated by adding the power consumption of all electrical appliances. Information on predicted annual operating costs for appliances should include the number and type of appliances, their individual energy performance characteristics, —from Energuide if applicable — and assumptions made regarding level of usage.)
- Load shedding and/or thermal storage systems must be adequately documented to permit technical evaluation.
  (Projected reduction in peak load based on load shedding or peak clipping must be documented.)
- The embodied energy in the construction materials used in the project.
  (Embodied energy of building materials is to be calculated using EXCEL software available through CMHC.)

Submissions will also be evaluated on the manner in which they have addressed the following:

- the use of **renewable energy sources** in the building operation:

2.2 Challenge Questions

3. What sources of energy supply were chosen and why? What demand will the house place on societal infrastructures for energy? Why was that level of demand chosen?

4. How does the design balance the requirements of increased durability against reducing the embodied energy of materials?

3. Resource Efficiency

3.1 Technical Criteria

Submissions **must** provide detailed performance characteristics of;

- Predicted annual **water consumption** — including interior household use and exterior use.
  (Total annual water consumption is to be calculated based on the following average usage patterns per occupant: —
  6 flushes/per person/day
  5 minutes shower/person/day
  3 minutes personal hygiene/person/day (tap running)
  1 cycle dishwasher
  1 cycle clothes washer
  17.5 litres/person/day set quantity for cooking/drinking
  Other major water consumption features (outdoor watering) should be identified.)

- alternative sources of water supply and/or use of grey water

- **material wastage** resulting from the construction process:
  (Total wastes generated during construction (as predicted by the design) are to be compared to conventional practices which result in an average of 2.5 tonnes of wastes. Waste reduction techniques should be identified with estimates made as to the quantities of wastes diverted from landfill.)

Submissions will be evaluated on the manner in which they have addressed the following:

- the **efficiency of resource use** at the production, construction, in-service and disposal stages:
- the expected **longevity/durability** of the design accounting for the life cycle of materials:
- the **reuse** of building materials and the use of **recycled** materials, and the **potential for reuse and recycling** of the materials used upon demolition of the house:
- the incorporation of **locally produced resources** in the design:

3.2 Challenge Questions

5. How does the design respond to regional considerations such as available building materials, resources, etc.
6. What demand will the house place on societal infrastructures for water supply? Why was that level of demand chosen?
7. What design lifetime did you choose for the house and why? How did that impact first-time costs? What provisions have been made to ensure that the house will meet its design lifetime?

4. Environmental Responsibility

4.1 Technical Requirements

Submissions will be evaluated on the manner in which they have addressed the following factors relating to the environmental impact of housing:

- the generation of **by-products of combustion** such as CO_2, SO_x, VOCs, and NO_x, and other considerations relating to outdoor air quality and atmospheric effects
- the presence of **CFC's** in materials and equipment in the house
- the generation of **waste water/sewage** and effects on municipal sewage treatment
- the generation of toxic wastes related to production of building materials, construction of the building and operation of the home **and the effects on municipal disposal facilities**
- the way in which the site plan mitigates the environmental impact of the house

4.2 Challenge Questions

8. What effects will the house have on local and global air quality and atmospheric effects?

9. What demand will the house place on societal infrastructures for:
   - waste water treatment,
   - storm sewer requirements, and
   - waste disposal?

   Why was that level of demand chosen?

10. In what ways does the design support the development of a sustainable community?

5. Affordability and Economic Viability

5.1 Technical Criteria

- Submissions **must** supply an estimated regional construction cost in 1991 dollars.
  (Identified costs are to be based on the following items.
  1. *Foundations: excavation, footings, foundations, drainage and backfill.*
  2. *Structure: slabs, floors and roofs, excluding walls.*
  3. *Exterior Enclosure: exterior walls, roof covering and insulation, soffits, windows, exterior doors and appendages.*
  4. *Interiors: interior walls, partitions, interior doors.*
  5. *Vertical Movement: exterior and interior stairs and handrails.*
  6. *Interior Finishes: floor coverings, ceiling and wall finishes and painting.*
  7. *Fittings, Equipment and Appliances: kitchen cabinets and cupboards, vanities and medicine cabinets, shelving, fireplaces, saunas, whirlpools and major appliances.*
  8. *Mechanical: plumbing, heating, air conditioning, ventilation and service connections.*
  9. *Electrical: service and distribution, lighting, power communications and protective systems.*
  10. *Site Work and Landscaping: grading, driveway, fences and landscaping.*
  11. *Project Overheads: supervision, general site labour, temporary services, security and clean-up.*

  Exclusions: design fees, survey, permits, mortgage fees, sales expenses, financing and carrying charges, serviced land, general overhead and profit.)

Submissions will also be evaluated on the manner in which they have addressed the following issues relating to economic viability:

- **affordability** —optimization of site plan and project design;
- adaptability to changing tenures;
- **'buildability' and ease of assembly** within the context of existing construction technologies;
- applicability to existing housing stock;
- suitability for wide spread adoption within the present context of the Canadian housing industry;
- **marketability** of the product.

5.2 Challenge Questions

11. Why do you think this design is affordable? What is your interpretation of affordability? What measures were taken in order to keep the house affordable while adding costs related to items such as improved energy efficiency or enviromental responsibility?
12. Can the house be built with technology and skills that are commercially available now? If not, identify which elements are not commercially available and when they will be. What aspects of the design do not meet current codes and standards? What changes would be required in order for the design to be widely adopted?
13. What opportunities does the design present for the development of Canadian technology and expertise? Why are these appropriate?
14. What do you think makes this design marketable? What lifestyle changes are implied for the occupants and how do you justify them?