SUSTAINABLE DEVELOPMENT AND HOUSING

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TOWARDS AN INVESTIGATION OF SUSTAINABLE HOUSING

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VUE D'ENSEMBLE DES LIGNES ENTRE LE DÉVELOPPEMENT DURABLE ET L'HABITATION

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1.0 INTRODUCTION

This paper investigates the relationship between sustainable development and housing. Its purpose is to demonstrate the need to reconsider prevailing patterns of residential development given the environmental impacts associated with today's housing and the many different strategies available to reduce these impacts. The paper examines the cumulative environmental impacts that have been incurred as a result of urbanization, and quantifies, where possible, the residential sector's contribution to these impacts. Opportunities to mitigate housing-related environmental impacts are also explored.

2.0 AGENTS OF URBAN CHANGE

For many years, planners, environmentalists and other interest groups have decried the exploitative, wasteful aspects of Canadian urban development patterns. The argument has been that sprawling, "leapfrog" settlements not only result in a highly energy intensive urban society, but also consume excessive amounts of land and fresh water resources.

These problems have been verified to varying degrees in different parts of the country. A common cause relates back to falling real energy prices throughout the twentieth century, which permitted urban growth to spread radially and at decreasing densities. Other factors which contributed to dispersed development patterns, particularly in the residential sector, include changing transportation systems, culminating with the advent of private automobiles as the preferred mode of travel, and changes in Canadians' values and expectations, reflected in modern community planning principles and practices.

2.1 Changing Transportation Systems

Around the beginning of the twentieth century, about one hundred years after the steam train gave birth to the modern city with a thriving and dense downtown, electric streetcars replaced horse-drawn vehicles and made wide scale suburban living around many cities feasible. The streetcar and railroad lines tended to anchor development to the tracks, roughly confining the spreading city to some sort of star shape.

Dispersed development patterns continued through the 1930s and '40s when buses and cars, which required no special infrastructure, such as overhead wires or steel rails, introduced a new level of transport flexibility. This flexible new service, particularly private automobiles, increased by 25 times the amount of urban space accessible for development within a given "time distance".[1] The most significant response to this new found accessibility was the further dispersal of residences, factories and offices. In the railroad suburbs, it meant that the construction of new housing subdivisions far from the railroad stations was suddenly entirely feasible. As land was much cheaper on the continually expanding fringe, lots also became much larger. Whereas in 1900, developers rarely advertized a home that was not within easy walking distance of a railroad station, later in the century, they rarely offered houses that did not have off-street parking and nearly always a garage.[2]

These trends, culminating with the automobile as the dominant mode of personal transportation, roughly coincided with rapid urbanization in Canada in the two decades following World War II. Not since the early 1900s, which constituted a period of unparalleled prosperity, did Canadian cities grow so fast. Between 1941 and 1951, Canadian urban centres grew by 3 million people, or 51%.[3] Another 5 million people were added to Canada's urban population in the succeeding decade (1951 - 1961), two-thirds of which went to the largest cities.[4] Returning veterans, rural-to-urban migration, immigration to Canada from abroad, and a dramatic increase in the natural growth of the population (the "baby boom"), increased the number of inhabitants in cities and the amount of area that cities occupied. Moreover, because of fifteen years of depression and war, there existed an immense pent-up demand for housing and other urban amenities among Canada's established (pre-war) urban population.

2.2 Contemporary Community Planning

In order to regulate the growth caused by Canada's burgeoning population and growing demand for housing, community planners looked to such planning concepts as "The Garden Suburb" and "The Neighbourhood Unit" to meet the challenge. Clarence Stein in particular left his mark in Canada with his neighbourhood unit concept known as the "Radburn Plan". Since the end of World War II, there has hardly been a metropolitan suburb planned in Canada that has not incorporated the following Radburn principles to a degree:

1) The superblock: a nearly exclusive residential area of 12-20 hectares with major roads on the perimeter to discourage through traffic;

2) Hierarchical roads: allowing different traffic needs to proceed only along specialized routes;

3) Separation of land uses: by the hierarchical road system; and

4) Parks as the focus: with large tracts of open space within the superblock.

The driving force behind these principles and behind present day city planning, is to avoid "incompatibility" between various land uses. To avoid incompatibility, or the adverse impacts of neighbouring uses, zoning was used to separate those uses which produced negative impacts, generally smoke stack industries, from those uses which suffered from such impacts, usually residential areas.

Over time, zoning by-laws evolved into an increasingly detailed set of controls, eventually being used to regulate housing densities and dwelling types. The end result of these detailed controls was often the socio-economic segregation of the population.

The differentiation of land uses into more and more detailed sub-sets and the spatial separation of different uses applied not only to the residential sector, but also to commercial and retail activities. Corner grocery stores and neighbourhood shopping strips, once a natural and integral part of the community, have largely been replaced by a hierarchy of single purpose commercial centres. Within residential areas, neighbourhood stores are now often prohibited, or discouraged, in favour of large, regional shopping plazas, far removed from the people who must use them. Those stores which do not easily fit into a shopping centre, such as furniture warehouses and lumber supply stores, are encouraged to spread out on large lots adjacent to arterial and other major roads.

Industrial uses are also isolated from other activities, and despite the fact that they are now much cleaner and less of a nuisance than in the past, regulations have become more onerous. For example, it is not just residents that are "protected" from industries under current zoning practice, but also other employment activities, such as office and retail. These activities are frequently prohibited from industrial zones, even as the distinction between industrial and office activities becomes increasingly blurred and difficult to determine. Many of today's industrial activities could even coexist with residential uses, although industrial-residential mixing is almost universally prohibited.

Public roads have also been separated from each other and a hierarchy produced that includes: controlled access freeways; major limited access arterials; arterial roads; major collectors; minor collectors; and neighbourhood streets. Ideally, intersections only occur between streets in the same category, or between streets in the immediate above or below categories. New arterial streets are designed with a very large right-of-way to permit eventual pavement widening and all adjacent residential uses are required to turn their backs on the arterial road and have access only from the interior parts of the neighbourhood. Frequently this reverse lot treatment applies to collector roads as well. The neighbourhood streets, on which houses abut, are designed in a curvilinear fashion to actively discourage through traffic. Thus the street pattern reinforces the land use pattern to create single use enclaves separated not only from other uses, but also from other enclaves of the same use.

One of the results of this hierarchy of roads and land uses is an increase in the amount of paved surface per capita. Many miles of streets are produced with no directly fronting land use, and shopping plazas, industries and other activities must provide a "sea of parking", as streets are no longer viewed as the appropriate location for stationary vehicles. Also, curvilinear neighbourhood streets, which discourage through vehicles, tend to discourage transit vehicles as well, restricting transit to the arterial roads which often have no abutting customer generating uses. The frequency and distance of automobile travel therefore increases dramatically as residents, forced to make use their cars, must navigate the local road pattern to reach the collector road, in order to reach the arterial, in order to travel to another arterial road, where the same process continues in reverse.

Therefore, while initially intended to relieve the problems of local pollution and urban congestion, planned communities, built according to the "Neighbourhood Unit" principles described above, have inadvertently contributed to today's more far reaching environmental problems. In combination with rapid rates of urbanization, continually increasing car ownership, and Canadians' and municipalities' apparent preference for single family homes, the result has been Canadian urban land use patterns largely characterized by:

1) sprawl and dispersal over large areas and low suburban population densities;
2) leapfrogging development patterns;
3) infrastructure patterns which are "locked in" and reinforce low density;
4) segregation of land uses; and
5) physical layouts which are insensitive to climate and require significant amounts of energy to satisfy demands for the movement of goods and people.

3.0 RESOURCE INTENSIVE DEVELOPMENT PATTERNS

The settlement patterns described above, often referred to as "urban sprawl", have led to the excessive use of land to accommodate our low density developments, and of energy to travel to and from our predominantly detached houses. Detached houses are also inherently less efficient than multiple house forms in terms of heating and cooling requirements, and they are considerably more expensive to service with linear infrastructure and other community facilities.

3.1 Dependence on Private Cars

In a sense, private cars can be viewed as both a cause and an effect of our dispersed development patterns. On the one hand, they have made development on the rural-urban fringe an affordable alternative to inner city development (at least in the short-term). On the other hand, it is this very development pattern which encourages, if not necessitates, massive automobile ownership throughout the country.

In 1969, there were about 6.2 million cars in Canada, or about one car for every 3.4 people. By 1981, the number of cars rose to about 10.2 million, or about one car for every 2.4 Canadians. In 1989, there were over 12.8 million cars in Canada, amounting to one for every two persons, or about 1.3 cars per household. Not only has the number of cars grown faster than the population, but the distance we are travelling in our cars has also risen. Between 1980 and 1988, the total number of kilometres travelled by passenger cars in Canada increased by about 22%.[5]

The increasing use of cars in Canada is directly responsible for numerous adverse environmental impacts. The most obvious of these is the enormous quantities of noxious gases that are produced when operating our cars. Annually, our cars each emit approximately 4,029 kilograms of CO_2, 34.4 kilograms of hydrocarbons, and 29.6 kilograms of nitrogen oxide (NO_x).[6] Road traffic is also the most significant source of carbon monoxide and lead emissions in the air. Locally, these emissions are our cities' single greatest source of air pollution. Globally, the build up of greenhouse gases produced from the burning of fossil fuels, is contributing to global warming, or the "greenhouse effect".

In 1988, Canada's transportation sector accounted for approximately 25% of total energy demand. Over 86% of this was consumed in the form of gasoline and diesel fuel (not including aviation gasoline), of which cars and trucks consumed the overwhelming majority.[7] In a typical city, 25% of the energy used is for transportation, 90% of which is to move people (about 15% of whom use public transit); the remaining 10% is for movement of goods, principally by truck.[8] It is estimated that nationally, over 13% of total energy consumed is for transportation via private automobile, with "journey-to-work" dominating the trips made.[9]

In comparison with other countries, these driving habits consume far more gasoline than would appear to be necessary to run successful urban economies. Table 1.1 shows that average per capita gasoline consumption in the City of Toronto is well over twice as high as in European cities, and over six times as high as in Asian cities. Moreover, since transit ridership is significantly higher in the Toronto area than in other Canadian cities (Table 1.2), gasoline consumption per capita in the rest of the country more likely approaches that of the American norm; that is, over four times as high as in European cities.

Table 1.1

URBAN GASOLINE CONSUMPTION PER CAPITA[10]

Urban Areas	Consumption Per Capita (Megajoules)	Relationship of Consumption in Toronto to Other Cities (ratio)
Toronto	34,813	1.0
U.S. Cities	58,541	0.6
Australian Cities	29,829	1.2
European Cities	13,280	2.6
Asian Cities	5,493	6.3

Table 1.2 **TRANSIT RIDERSHIP IN CANADIAN CITIES**[11]		
Municipality	Rides Per Capita Per Year	Passengers Per Vehicle Hour
Metro Toronto	211.3	53.1
Ottawa-Carleton	140.9	46.6
Greater Vancouver Regional District	88.7	36.1
City of Regina	47.7	33.0
City of Saskatoon	66.7	38.0

3.2 Reducing Transportation Energy Requirements

The literature on community planning and urban form identifies two basic ways in which energy needs can be reduced in the transportation sector: people can be encouraged to travel less (i.e. frequency and distance); and they can be encouraged to travel by more energy-efficient means. The former implies arranging land uses so that there is less need to travel, while the latter implies aiming for land-use patterns that are conducive to public and nonmotorized transport. Some of the more relevant structural variables that commonly contribute or detract from these ends include: urban size, shape, density and land use mix.

Urban Size and Shape - Although a considerable amount of work has been done on the relationships between transportation energy requirements and urban size and shape, the results have been contradictory, and it has been very difficult to establish any cause-effect. The forms investigated have been highly abstract, and overall, it appears that travel needs depend less on the size and shape of a settlement than on the internal arrangement of activities; specifically, on the physical separation of activities, determined in part by density, and in part by land use mix.[12]

Density and Land Use Mix - A study of Metropolitan Toronto conducted in 1980, concluded that as density increased tenfold, from 3.9 to 39 dwelling units per hectare, weekday vehicle travel, measured in km per capita, decreased by 40%. Higher densities not only reduce the frequency and distance of automobile travel, but also enhance the opportunities for public transit, walking and cycling. Overall, the authors note that energy savings as high as 50% can be realized if higher density developments (67 to 94 dwelling units/hectare), were to replace low-density, urban sprawl.[13]

In 1989, the relationship between density, transit, and automobile use was verified empirically using 32 cities from around the world.[14] The study concluded that the amount of energy devoted to transport depends on "activity intensity" - a measure of city land use based on the concentration of residents and jobs per hectare in a metropolitan area. As the following data for ten American cities illustrates (Table 1.3), gasoline consumption and automobile use appears to be inversely related to overall urban densities and to the strength of the inner city (measured in persons and jobs per hectare). Transit use, on the other hand, appears to be a function of both inner city strength, and the extent to which a city provides for its automobile and non-automobile modes (Table 1.3). Generally, the more jobs in the city centre, the more viable is transit, which has as its justification, large numbers of people all going to the same place.

Table 1.3

TRANSPORT CHARACTERISTICS AND URBAN FORM

GASOLINE CONSUMPTION/CITY		ACTIVITY INTENSITY/ INTENSITY OF LAND USE (persons and jobs/ha)			CENTRAL CITY STRENGTH		PROVIDING FOR AUTO AND NON -AUTO MODES	
City	Megajoules of Gasoline Per Capita	Overall Urban Density Pop. & (Jobs)	Central-City Density Pop. & (Jobs)	Inner-Area Density Pop. & (Jobs)	Percent Pop. & (Jobs) in CBD	Percent Pop. & (Jobs) in Inner-Area	Transit: Vehicle kms of Service/ Capita	Percent Trips to Work via Transit
Houston	74,510	9 (6)	6 (443)	21 (26)	0.1 (11.6)	16.6 (41.1)	9	3.3
Phoenix	69,908	9 (4)	17 (67)	19 (24)	0.5 (3.9)	3.7 (10.6)	7	2.2
Detroit	65,978	14 (6)	11 (306)	48 (20)	0.1 (6.6)	31.6 (29.6)	17	4.1
Denver	63,466	12 (8)	19 (263)	19 (17)	0.4 (11.5)	30.9 (49.7)	25	6.5
Los Angeles	58,474	20 (11)	29 (472)	30 (14)	0.1 (4.8)	31.3 (43.3)	27	7.7
San Francisco	55,365	16 (8)	90 (713)	59 (48)	1.1 (17.0)	21.3 (34.4)	50	17.0
Boston	54,185	12 (6)	126 (386)	45 (33)	2.7 (15.9)	24.3 (34.6)	26	16.1
Washington	51,241	13 (8)	8 (584)	44 (38)	0.1 (16.1)	21.4 (32.5)	40	14.1
Chicago	48,246	18 (8)	16 (938)	54 (26)	0.1 (12.3)	42.3 (44.9)	42	18.3
New York	44,033	20 (9)	217 (828)	107 (53)	2.8 (22.9)	39.5 (41.9)	58	28.3
Average	58,541	14 (7)	54 (500)	45 (30)	0.8 (12.3)	26.3 (36.3)	30	11.8

The data indicate that gasoline consumption in U.S. cities varies by about 40% between newer, low-density, relatively weak-centred cities such as Houston, and older, high-density, relatively strong-centred cities such as New York. This suggests a theoretical potential for fuel savings of some 20% to 30% in cities like Houston and Phoenix, if they were to become more like Boston or Washington in urban structure. Overall, a stylized picture emerges of a low transportation-energy city with a dense form, a strong centre, and an intensively utilized inner area that provides the backbone for a significantly better transit system and more biking and walking.

3.3 Detached Houses and Urban Infrastructure Requirements

The popularity of detached houses in post-war Canada has contributed significantly to our dependence on private automobiles. After World War II, most of the new housing built to accommodate expanding city populations in Canada was provided in the suburbs, and most of this was low-density developments of mainly one- and two-family houses and, occasionally, low-rise apartments. Since detached houses are usually incorporated into development patterns that are much less dense than those normally associated with other house forms, they require much more land to accommodate any given population. As Table 1.4 demonstrates, single-family detached homes, at an average of 45 persons per net hectare, house some 58% less people per net hectare than row-houses (at an average of 108 persons per net hectare); approximately 71% less people than walk-up apartments (at an average of 156 persons per net hectare); and anywhere from 76% to 97% less people per net hectare than high density, multi-family housing.

Table 1.4

TYPICAL DENSITIES OF DIFFERENT HOUSE FORMS[15]

Density	Typology	Storeys	Units/Net Ha	Persons/Net Ha
Low	1-family detached	1-2	12-17	43-48
	2-family	1-2	19-29	48-84
Medium	row house,	2-3	24-48	72-144
	garden/walk-up apt.	3-4	48-96	120-192
High	multi-family (low)	5-10	96-192	192-360
	multi-family (med.)	10-16	192-240	360-480
	multi-family (high)	16+	240-960	480-1680

The infrastructure needed to service these low residential densities is illustrated by the relative street lengths per unit required by different house types (Table 1.5). These street lengths are also indicative of other linear infrastructure which usually run parallel to roads, such as water and wastewater systems, sidewalks, street lights and gas lines.

Table 1.5

LINEAR INFRASTRUCTURE REQUIREMENTS[16]

Residential Option	Density (units/ha)	Relative length of streets (per unit)
Apt. blocks, 8 floors, 6 units per floor	87	1.0
Apt. blocks, 4 floors, 6 units per floor	73	1.7
Triplexes (groups of 4)	55	2.8
Duplexes (groups of 4)	37	4.2
Detached single-family bungalows	10	17.5

Overall, for all linear infrastructure, the detached housing option requires approximately four times more infrastructure per unit than the duplex option. For municipalities, this also means four times more distance to travel for such services as snow and garbage removal, school bus routes, and public transit. It also means considerably more expensive infrastructure renewal and expansion.

This last point has been a particularly contentious issue in many municipalities, especially where obsolete and deteriorating storm and wastewater systems are adversely affecting surrounding aquatic ecosystems. This in turn affects one of the most important aspects of urbanites' perceived quality of life: the recreational potential of their surrounding lakes, rivers and streams.

In the residential sector, the amount of wastewater produced is a function of household water use, itself a component of municipal water use. In 1981, some 640 million cubic metres of fresh water, or over 16% of total water consumption in Canada, was consumed for municipal uses (Table 1.6). Approximately, 63% of this, or over 10.3% of total water consumption in the country, was accounted for by the residential sector (Table 1.7).

Table 1.6

WATER USE IN CANADA - 1981[17]

(millions m^3 per annum)

ACTIVITY	CONSUMPTION
Agriculture	2,412
Mineral Industry	178
Manufacturing	494
Thermal Power	168
Municipal	640
Total	3,892

Table 1.7

MUNICIPAL WATER USE[18]

RESIDENTIAL	63%
COMMERCIAL	14%
PUBLIC	5%
OTHER	18%

The average Canadian now uses about 285 litres of fresh water per day at home for drinking, cooking, washing and sanitation.[19] Other sources suggest we consume as much as 360 litres per capita per day.[20] (Table 1.8 illustrates indoor household water use in Canada by end use demand.) This is an excessive amount of water in comparison with other countries, such as

Sweden and the United Kingdom, where average water use is under 200 litres per person per day. In West Germany and France, it is about 150 litres per person per day.[21]

Table 1.8

INDOOR WATER USES[22]

Bathing and Personal	28%
Laundry	23%
Toilet	45%
Drinking and Cooking	4%

Much of Canada's excessive water use can be attributed to inefficient household appliances and plumbing fixtures. For example, while about half the average Canadian's daily water supply is flushed away in toilets using upwards of 20 litres per flush, West German toilets use as little as 9 litres per flush, and those routinely installed in Scandinavia since 1975, get by with as little as 6 litres.[23] There are also high efficiency toilets on the market today which function with as little as 2 to 4 litres, sometimes by using a jet of air along with the water.

Attention to aging plumbing fixtures could also reduce Canadian water consumption. A dripping tap for example, typically wastes between 30 and 100 litres of fresh water per day and, on average, household water leaks account for about 5 to 10% of total water use in North American homes.[24] In many instances, a new ten cent washer or simply tightening a seal would rectify the problem.

Deteriorating Infrastructure - As Canadians consume excessive quantities of fresh water for drinking and cleaning, the resource becomes a carrier of body wastes, detergents and other cleaning agents. To dispose of these waterborne pollutants, systems of sewerage were introduced in many Canadian municipalities as early as the 1860s, however, treatment did not become common practice until the years after World War II. Until the 1970s, maintenance of these wastewater facilities remained at an acceptable level, largely because economic conditions were good, and many facilities were relatively new. Subsequently, increasing resistance to rising taxes, higher interest rates, and a growing demand for other community services, has made reconstruction more difficult and more expensive. This has resulted in a deferral of necessary work on infrastructure upgrades and expansion, and a growing back-log of maintenance and replacement work.

In Ontario for example, although 83% of the population is served by some 371 sewage treatment plants throughout the province, over 37% of these facilities are not up to standard. Further, in a survey of 412 of Ontario's 434 municipalities, representing a total of 83,000 km of watermains, it was found that the average age of the province's pipes is 40 years, and that watermains typically experience about 25 breaks per 100 km per year.[25] Broken water mains and leaks in the system lead to increased overall consumption and waste, which in turn leads to higher water treatment costs and added pressures on resources. Nationally, emergency repairs for water distribution systems have increased from 17 to 30 per 100 km of main during the past 15 years.[26] For Canada as a whole, some 18% of municipal water use is lost, or unaccounted for.[27]

Similarly, sewer failures have increased from 6 to 17 per 100 km of sewer over the past 15 years.[28] Infiltration and inflow rates have increased and sewer capacity has been reduced by these extraneous flows. This has increased sewage treatment costs, and in areas where only limited treatment can be provided, to increased sewer overflows and raw discharges to the nearest watercourses. According to the Communauté urbaine de Québec for example, 500 million litres of untreated water and 50 metric tons of raw sewage are pumped into the St. Lawrence River each day.[29] Nationally, as of 1985, some 8 million Canadians resided in municipalities where no sewage treatment had yet been provided to protect receiving waters.[30]

Where septic systems have been installed in parts of the country, the technology has often proven faulty and many tanks are deteriorating. The Sewell Commission on Planning and Development Reform in Ontario has stated that:

> "Province-wide, reports of septic system problems and failures are increasing (in Ontario). In the short term, septic system failures mean public health hazards from exposure to sewage and its attendant diseases. In the long term, drinking water is at risk of contamination. There are now close to one million septic systems installed in Ontario. Local health units report that the number of complaints received and sanitary investigations conducted climbed to 9,067 in 1990, from 5,154 in 1984. The standard guesstimate is that 30% of all septic systems are failing. A 1990 study of 560 wells found that 68% of shallow wells and 22% of drilled wells had unacceptable bacteriological counts. Fully 29% exceeded the Drinking Water Guidelines for nitrates, the critical contaminant from septic systems.[31]

Obsolete Infrastructure - Continued urban growth, and the resulting pressure on the assimilative capacity of our streams, rivers and lakes to absorb the residual organic loadings from wastewater plants, has also reduced the effectiveness of wastewater systems. In many instances, the result has been that a large number of existing plants are no longer capable of producing an effluent quality that protects their receiving waters. In these areas, improved treatment from primary to secondary levels and from secondary to best available technology is now needed.

Part of the problem is that in older urban areas, it was normal practice to provide for the combined flow of urban runoff and wastewater in the same sewer. With such a system, as urban residents and their governments use water to irrigate lawns, parks and gardens and to wash streets, they introduce a wide range of pesticides, herbicides, fertilizers, suspended solids, salt, oil and grease, heavy metals, bacteria and other oxygen-depleting pollutants. Naturally occurring precipitation has the same effect. During rainfall periods, the major portion of combined sewer flows, which exceed dry weather flows by 50 to 100 times, is discharged directly (raw) to the receiving waters at combined sewer overflow outlets.[32]

A typical rainfall in the Toronto area, for example, dumps approximately 4.5 billion litres of water that rushes off roofs, roads, and parking lots into sewers and often into combined storm and sanitary sewer lines.[33] This sudden pulse of stormwater, already contaminated with animal feces, oil, grease, metals and other pollutants, mixes with untreated human sewage and enters the rivers in the area or descends on the sewage treatment plants designed to carry only some of the extra burden. In order to prevent flooding at the plants, the sewage/stormwater mixture is given only partial treatment and is diverted into the lake. The resulting high levels of bacteria is largely responsible for the beach closures along the Greater Toronto Waterfront every summer. Beach closures in Ottawa and other cities throughout the country are often a result of the same problem.

3.4 The User-Pay Principle

Throughout the country, whether it is for general maintenance, replacing obsolete infrastructure, improving facilities to meet more stringent standards, or expanding facilities to meet growing demand, municipalities are finding it increasingly difficult to pay for the required work on water and wastewater systems. Part of the problem is that in many cities, the price of water does not reflect the real value of the resource, or even the cost of providing and disposing of it. Lacking any economic incentive, consumers tend to use water indiscriminantly, and municipalities are unable to generate the revenues necessary to maintain, upgrade and expand their facilities.

A more realistic pricing system would not only provide additional revenues which could be earmarked for infrastructure renewal, but would invariably reduce water demand. This latter relationship has been demonstrated empirically in Alberta, where Edmonton homes, which have water meters, use approximately half as much water as those in Calgary, which are unmetered.[34] Despite this relationship, however, very little effort is being made in Canada to use water pricing as an incentive for rational, efficient resource use. Instead, water rates and charges generally ignore rehabilitation and eventual replacement costs and are related to little more than token charges to provide revenue offsetting construction and operating costs.

In 1985, the Pearce Commission (Inquiry on Federal Water Policy, 1985), proposed the following pricing system, which would require the price of water to be at least equal to the cost of providing it. This implied the following elements in the rate schedule:

1) Commodity Charge: The first element is a price per cubic metre of water used, or a commodity charge. Such a price should be set at a level equal to the incremental (or marginal) cost of providing the water, that is, the long-term marginal cost of additional supplies. This will ensure that users recognize the cost they impose on the system when they use water.

2) Fixed Rate: The second element is a fixed charge. Because the marginal cost is often lower than the average cost (because of economies of scale in water systems), a fixed rate per year or per month can appropriately be levied to cover the difference between total costs of the system and the revenue collected from commodity charges. The same principles can be applied to sewage and wastewater systems.

3) Capital, Operating And Opportunity Costs: If the pricing system is to account for both operating and capital costs, including depreciation, it should also recognize the value of the water itself, including its opportunity cost wherever limited supplies are demanded for other useful purposes.

4) Environmental Compensation: Finally, where appropriate, the pricing system should embody an allowance for environmental damage associated with water supply or wastewater disposal. Charges for wastewater should, ideally, take account of both the quantity of effluent discharged into the system and the concentration of pollutants it contains.

By reducing the amount of water consumed, and hence treatment capacity required, the above pricing system would help reduce the cost of water and wastewater facilities. It would also help generate the necessary revenue to cover the cost of these facilities. In addition, the resulting lower demand would reduce environmental pressures on water resources, and by demonstrating users' willingness to pay for water, the pricing system would help allocate supplies among uses and users so that the highest value is generated from limited resources. Finally, a suitable pricing system would help ensure that the cost of water services is equitably borne by the beneficiaries, according to the benefits they receive.[35]

3.5 Land Use Change

In addition to increasing the cost of expanding and maintaining urban infrastructure, our dispersed development patterns also consume excessive amounts of otherwise renewable land resources. Since North America's early European settlers were essentially agrarian, attracted to the areas with the most agricultural potential, historically, Canada's prime agricultural land has been the most vulnerable to the pressures of urbanization. Nationally, there is a close relationship between the location of urban areas and good quality agricultural land. More than 55% of Canada's classes 1-3 agricultural capability land lies within a 160 km radius of Census Metropolitan Areas.[36] The Quebec-Windsor axis, where approximately 54% of Canadians presently reside, contains more than one-fifth of Canada's Class 1, 2 and 3 farmland and accounts for more than one-third of the cash receipts generated by Canadian farmers.[37] Canada's prime agricultural land is under continuous pressure from urbanization, particularly in Ontario and Quebec, where approximately 10% of Canada's prime agricultural land, and about 38% of all Class 1 lands are in and around the cities of Toronto and Montreal.[38]

The Canada Land Inventory (CLI) indicates that only 11% of the country's 992 million hectares is capable of any form of agricultural production, and less than 5% is prime agricultural land (classes 1-3), capable of producing crops.[39] However, the CLI agricultural capability system evaluates agricultural land primarily on the basis of soils and does not adequately consider the effects of climate on production. With a harsh climate and water deficiencies in the summer months, it is estimated that less than 1% of the nation's total area is suitable for agricultural purposes.[40]

The problem in Canada's industrial axis, and throughout the country, is that land is allocated to whichever use yields the most "value" to society. With the concept of value being determined in the market place, the fate of agricultural land in Canada is largely being decided by the real estate market, despite the fact that the allocation of land to the highest bidder through market competition may not always be the land's best use. This is particularly true where unique and sensitive lands are at stake.

For example, in the 1960s, the Niagara Fruit Belt in Ontario, which produces as much as 80% of all Canada's fruit, lost over 261 hectares of land every year, primarily to the construction of new residential communities.[41] Throughout the 1970s, the rate of loss was even higher. In the late 1970s and early 1980s in and around Montreal, about 8,700 hectares of the best farm land in Quebec were lost every year.[42] In seven years, Alberta lost no less than 16,000 hectares to Edmonton and Calgary.[43] And in British Columbia, approximately 40,000 hectares of farm land were lost between 1962 and 1972, with the Okanagan Valley suffering a similar fate as that of the Niagara Fruit Belt.[44]

A study by Environment Canada which analyzed urbanization trends between 1966 and 1986 in 70 "urban-centred regions" (UCRs) across the country, indicated that some 301,440 hectares of rural land were converted to urban and urban-related uses over the 20-year period.[45] Approximately 58% of this land had high capability for agricultural production.

Fortunately, in recent years, there has been a reasonably consistent improvement in the efficiency of converting rural land to urban uses. Between 1981 and 1986, the 70 UCRs studied by Environment Canada converted rural land at a rate of 64 hectares per 1000 increase in population, almost one-half that of the previous five-year period, which converted 119 hectares per 1000 increase in population. Predictably, the most populous UCRs, where land commands the highest prices, converted land most efficiently. During 1981-86, the largest UCRs took over 53 hectares of land for every 1000 increase in population, whereas the smallest centres converted 242 hectares per 1000 increase in population (Table 1.9).

Table 1.9

GROWTH AND CHANGE WITHIN UCRs BY POPULATION CLASS, 1981-86[46]

Population Class (No. of UCRs)	Area Increase %	Population Density pop/ha	Population Increase %	Rate of land Conversion ha/1000 pop.
25,000 - 50,000 (26)	3.3	9.0	1.5	242
50,001 - 100,000 (18)	4.0	9.8	2.9	141
100,001 - 250,000 (13)	4.9	12.8	3.6	104
250,001 - 500,000 (4)	3.2	12.4	5.2	50
> 500,000 (9)	6.6	19.5	6.3	53
Average for 70 UCRs	5.4	16.5	5.4	64

If current trends continue, an average land consumption rate of over 60 hectares per 1,000 increase in population will be required to accommodate the millions of people that will be added to Canada's urban population over the next several decades. The scene of most of this development activity will continue to be in large metropolitan areas and suburban expansion zones. Moreover, all indications are that in the next 15 years, land supply will become a more problematic issue than it has been in previous decades.[47] Many regions are using up the Stage One lands in their Official, or Master Plans and may soon require the designation of additional growth areas. As development reaches the inner edges of agricultural zones established in the 1970s, agricultural land designations will be coming under increasing pressure in British Columbia's Lower Mainland, in Alberta, and in Ontario and Quebec.[48]

In the Quebec-Windsor axis, the population is projected to increase to 14.9 million by 2001, with a land consumption rate of 42.1 hectares per 1,000 increase in population.[49] Therefore, while the population of the axis will increase by 13.6% between 1981 and 2001, the amount of land consumed directly for urban purposes will increase by 21.5%.[50] Including lands converted to indirect, or urban-oriented ("urban shadow") uses, such as sand and gravel pits, sod farms, autowreckers, landfills, recreational facilities, and so on, it is estimated that some 668,000 hectares of prime agricultural land will be lost in Canada's urban heartland by the year 2000.[51]

Canada's best farmland, therefore, is facing continuing competition from urbanization. Farmers must deal with this pressure by trying to make farming more economical, knowing their land could bring better financial returns if put to urban uses. The farms that have managed to survive this pressure have generally achieved the necessary economies of scale, and have successfully taken advantage of the right combination of mechanization, chemicalization and agricultural subsidies. Increasingly, however, this combination is compelling farmers to produce more from their land than it can naturally give, ultimately destroying the very resource they are trying to sustain. This is urbanization's less talked about, secondary impact on agricultural land. That is, not only is prime farmland being paved over to make room for the built environment, but urbanization (in combination with the "globalization" of market economies), has also helped transform relatively small-scale, diversified and self-sufficient regional farming operations into large-scale, unsustainable industries serving the world market.

3.6 Housing Intensification

Encouraging "residential intensification", an overarching concept used to describe various development forms that increase the number of housing units in a community, is one way of reducing the amount of land consumed by housing. Typical ways of intensifying residential land uses include:

1) Conversion: increasing the number of households that can be accommodated in existing detached or semi-detached dwellings through renovation and/or additions;

2) Infill: constructing new housing within existing serviced residential areas;

3) Redevelopment: new housing on underutilized, or obsolete (usually non-residential) sites;

4) Adaptive Reuse: housing on sites and in buildings originally zoned non-residential; and

5) Suburban Densification: increasing densities in new subdivisions through subdivision control to encourage smaller lot sizes, reduced set-backs, narrower right-of-way widths, and so on.

In addition to reducing land requirements, housing intensification tends to reduce per unit housing costs, it can make more equitable and efficient use of existing infrastructure and community services, and it can help realize the transportation efficiencies associated with a denser, more diversified mix of residential, commercial and other land uses.

A 1991 Housing Intensification Charette, organized by the Canadian Urban Institute, and a 1991 study on the effects of urban intensification prepared for Ontario's Ministry of Municipal Affairs, outline various other benefits associated with residential intensification (Table 1.10).

Table 1.10

BENEFITS OF HOUSING INTENSIFICATION[52]

Social Benefits	- encourages affordable housing through lower per-unit costs; - increases the probability of better matching unit size and type with household requirements; - improves access to community amenities; and - enhances human vitality, intimacy and neighbourliness normally associated with mixing house types, shops and other vital urban activities.
Economic Benefits	- lowers infrastructure costs per new housing unit; and - makes more efficient use of existing infrastructure and community services.
Environmental Benefits	- reduces residential land requirements, thereby facilitating the protection of agricultural land, wetlands, woodlots, wildlife habitat, and other sensitive areas; - facilitates non-vehicular travel; - increases the feasibility of public transit by reducing automobile dependence; - increases average envelope efficiency by encouraging the development of multiple units; - reduces per capita materials and operating energy needs by lowering average per capita residential space requirements; - shortens transport distances, thus reducing the cost of collecting both residential construction and household waste; - reduces the cost of other services such as school buses, deliveries, and postal service.

Opportunities for residential intensification exist in most Canadian cities. In the City of Ottawa, for example, an evaluation of lots used for very low density uses as of June, 1984, showed that some 17,200 new units could be constructed by redeveloping these properties.[53] Further, approximately 1,670 lots in Ottawa have the potential to be subdivided by severance to create new residential lots, and there are thousands of acres of open space, some parts of which may be used for residential purposes in the future.[54] In the City of Toronto, an estimated 800 hectares of underused land could be devoted to residential intensification, and about 2,200 hectares in the suburbs of Scarborough, North York and Etobicoke could also be redeveloped in this way.[55]

The "over-consumption" of housing by elderly households is a unique example where one method of residential intensification - conversion - can address social, economic and environmental issues. In 1982, close to 85% of elderly homeowners lived in single detached dwellings.[56] The majority of these households, almost 75%, occupied two or three bedroom dwellings. Using the one-person-per-bedroom standard, over half of elderly owners were judged as "over-housed", suggesting a significant mismatch between the space requirements of older families and the actual size of the dwellings which they occupy. The creation of an accessory apartment in many of these cases would not only make better use of the existing housing stock, but would also enhance housing affordability for both the elderly homeowners, who are often "cash-poor" and "house-rich", and the tenants of the accessory apartments. Home-sharing via conversion also facilitates social integration and can help relieve some of the isolation often experienced in elderly households.

3.7 Regulatory Reform

Although housing intensification is a reasonably efficient approach to accommodating modest growth and change in Canadian communities, the process is often constrained by procedural and technical concerns related to the planning process, and by public opposition.

In order to help address the procedural and technical concerns related to planning, CMHC recently embarked on a national program - "Affordability and Choice Today" (A.C.T.). A.C.T. is designed to stimulate regulatory reform in residential construction. Its objectives are to promote housing choice, affordability, quality and innovation. Some of the key areas requiring regulatory reform include: land development standards; the land development approval process;

the inspection process; and residential renovation. Each of these areas has either a direct or indirect bearing on housing intensification. However, of particular importance are land development standards, including land use standards and site servicing standards.

Land use standards relate to the use of land, development densities, building heights, and so on. Once density and site requirements are established or revised to accommodate a particular development, zoning bylaws must be changed and Official Plans must often be amended to enable the development. Coordinating the amendment of Official Plans, and changing housing policies in a coherent and timely manner often proves to be a major stumbling block in the housing intensification process. Compounding these problems is the amount of public opposition that often accompanies conversion, infill and redevelopment projects. This opposition, known as the "Not In My Backyard", or "NIMBY" syndrome, typically focuses on fears about over-crowding, loss of community character and declining property values.

Site servicing (engineering) standards relate to engineering requirements such as right-of-way widths, storm and wastewater systems, utilities, and so on. The general argument is that today's standards may be excessive, outdated and overly rigid, preventing the use of new technologies, and innovative, cost-saving approaches to community planning and design.

In order to help promote more flexible and responsive land use and site servicing standards, A.C.T. has provided funding for numerous innovative demonstration projects, such as infill housing on small lots, "Garden Suites", stacked fourplexes on single family lots, expandable suburban houses, and more.

Many of these house forms highlight the incompatibility between zoning ordinances and demographically driven changes in housing demands and needs. Additional research and demonstration related to the development of more flexible and responsive houses, as well as to the regulatory reforms required to facilitate their construction, is therefore needed to determine whether today's zoning by-laws and other interventions are having desirable effects. Additional R&D is also required to develop ways of dealing with the public's concerns about housing densities, site requirements, and urban design principles. In general, it must be demonstrated that if properly planned and designed, housing intensification can help resolve many of today's social, economic and environmental challenges, without negatively affecting neighbourhood character.

3.8 House Form

By favouring the creation of more multiple dwellings, housing intensification can also help reduce space heating requirements in Canada. Currently, approximately 60% of Canada's existing stock of housing is made up of low-density, detached units. However, by reducing exposed wall areas and improving the ratio of exposed surface to volume, multiple dwellings are inherently more energy efficient than detached houses.

A 1985 study in Sault Ste. Marie found that semi-detached and townhouse units consume an average of 66,400 megajoules/unit annually, and that apartments consume 33,200 megajoules/unit annually - 20% and 60% less respectively than detached units at 83,000 megajoules/unit annually.[57] Table 1.11 illustrates the inherent inefficiencies associated with detached houses. All else being equal, detached houses can consume anywhere from 15 to 67% more energy than other common ground-oriented housing options, primarily because of their high exposed surface to volume ratio.

Table 1.12

ENERGY EFFICIENCY OF ALTERNATIVE HOUSING TYPES[58]

Type of Unit and Zoning	Million Btus Per Year for Space Heating	Energy Savings
One-storey single family home	64	Base
Two-storey single family home	59	15%
Two-storey duplex	45	30%
Two-storey triplex	42	35%
Low-rise condominium or apartment, same space as above units	38	40%
Typical low-rise apartments with less space than the above units	21	67%

Many other simulation and empirical studies verify this relationship between house form and space heating requirements. Generally, savings of up to 33% can be realized by simply foregoing the detached option in favour of a more efficient form.

Detached houses also tend to circumvent efficiency gains in other areas, such as cogeneration and district heating, which require relatively high levels of population density to be economical. The overall efficiency associated with the simultaneous production of electricity and useful heat (cogeneration), can be as high as 80 to 90%.[59] This is a significant improvement over conventional thermal power stations which convert primary fuel into electricity with a maximum efficiency of about 35%; some 50-60% of the energy is converted to low-grade heat and discharged into the atmosphere or into rivers. Since keeping warm in winter is one of the most easily satisfied of our energy needs, requiring only a very low quality of energy capable of heating air to about 20 degrees celsius, discharging this low-grade heat (which could be used to heat houses), is inefficient and expensive -- particularly as most of the low temperature heat supplying our houses now comes from high quality sources, such as oil, gas and electricity (Table 1.12)

Table 1.12

RESIDENTIAL ENERGY PATTERNS[60]

	CONSUMPTION		PRINCIPAL ENERGY SOURCES			
End Uses	% Total Energy	Average Annual Cost/ Household	Gas	Electric	Oil	Other
Space Heating	67%	$800.00	59%	19%	20%	2%
Water Heating	17%	$200.00	53%	45%	2%	---
Appliances	14%	$175.00	---	100%	---	---
Lights	2%	$25.00	---	100%	---	---
Total Energy	100%	$1,200.00	51%	30%	15%	4%

Using high quality sources of energy for low quality end uses, such as home heating, is also inefficient and expensive as the energy is no longer available for any other jobs. If, on the other hand, these high quality sources of energy were reserved for high quality end uses, such as heating industrial furnaces, most of the energy would still be available in a highly organized, highly useful form after being exhausted from these furnaces. Rather than discharging this energy, it could then be used for heating homes via a district heating network.

The potential for the introduction of cogeneration and district heating networks depends, among other things, on development densities and land use mix. The system is used extensively in Scandinavia and in Eastern Europe, and to some extent in other European countries. In Denmark for example, about 40% of the heat consumption in the residential and commercial sectors is provided by district heating. The corresponding figure for Sweden is 25%.[61]

In Canada, although approximately 67% of all the energy delivered to our houses is required as space heating (Table 1.12), cogeneration and district heating remains largely untapped, partly due to our relatively low energy prices, and partly due to our development patterns. A detailed study conducted in the U.K., suggested minimum housing densities of approximately 44 dwelling units per hectare before cogeneration and district heating can be a viable alternative.[62] The average density of much of Canada's stock of detached houses, however, is only about 10-20 units per hectare, and much of this is located in single-use residential districts.

3.9 Thermal Efficiency and R-2000 Technology

Although detached houses are inherently less efficient than multiple units, Canadian home-owners and new-home builders have made significant strides in reducing space heating requirements in Canada's housing stock by improving the thermal efficiency of building envelopes. Between 1973 and 1987 in Canada, per household energy consumption dropped some 32.5%. Over half of this decline was due to improvements in the energy efficiency of new housing combined with thermal retrofits in the old stock.[63]

Achieving thermal efficiency is cheapest when built in from the start. The extra capital cost of an R-2000 house, for example, can be anywhere from 5-7%. However, these houses generally cost up to 70% less per year to heat and cool. Gross annual energy savings over conventional construction has been estimated to be between $310 and $1,230 depending on climate, the price of energy and the quality of comparable conventional housing.[64] Moreover, these represent savings to homeowners only. More important, are the cumulative energy savings of R-2000 houses. According to a 1986 study by the Ontario Ministry of Energy, Canada's 5,000 R-2000 homes each save about 12 megawatt hours annually. This represents a cumulative energy savings of approximately 60 gigawatt hours each year. This reduction in demand helps defer the need for new power plants, which in turn translates into significant capital savings for public utilities. Deferring the construction of new power plants, transmission lines, transformer stations, pipelines and so on, also saves operating costs every year, it saves infrastructure maintenance and replacement costs, and it saves the decommissioning costs of plant closure. Further, avoiding the many social and environmental "externalities" often associated with energy projects (eg. acid rain), represents what are perhaps incalculable economic savings. Taking these factors into consideration, the potential savings associated with residential energy conservation is in the order of billions of dollars.

Canada's R-2000 Homes Program represents one attempt to capitalize on these potential savings. While the program aims for performance, rather than setting out specific designs or standards, R-2000 houses frequently share several common innovative features, including:

1) high levels of insulation, or "superinsulation" in exterior walls, roofs and basements;
2) high quality, continuous, sealed air-vapour barrier to reduce air leakage, heating costs, winter drafts, destructive condensation and summer dust;
3) continuous mechanical ventilation which often includes a heat recovery device;
4) high quality double or triple glazed windows with durable weather seals;
5) two-door, air lock vestibules to help prevent winter winds from entering the house;
6) energy efficient space heating systems, water heaters, appliances and lighting; and
7) south-facing solar orientation, with appropriate window to wall area ratios.

3.10 Passive Solar Design

The final feature noted above, solar orientation, is becoming increasingly important as more efficient building envelopes continue to reduce conventional heating fuel requirements, thereby increasing solar energy's contribution to total heating loads.

Developed in 1982 by the National Research Council, the "HOTCAN" model has been used to help demonstrate this relationship between building orientation, envelope efficiency, and heating loads. For a standard 150 m^2 house with 22 m^2 of windows (and various other architectural constants), heating loads were determined for 12 locations across Canada. Three insulation levels were considered in the study: 1978 and 1984 building code standards, and super-insulated houses. Table 1.13 lists the results.

Table 1.13

BUILDING ORIENTATION AND SOLAR GAIN

Location	Percent increases in heating loads for units oriented north instead of south			Percent increases in heating loads for units oriented east/west instead of south		
	1978	1984	Super	1978	1984	Super
Vancouver	14	35	45	6	20	27
Edmonton	12	22	25	5	12	15
Suffield	17	32	37	9	17	21
Swift Current	14	26	29	7	16	18
Saskatoon	14	26	30	6	14	17
Winnipeg	12	23	26	6	13	15
Toronto	10	23	28	4	11	18
Ottawa	11	23	28	5	12	16
Montreal	12	24	29	5	12	17
Fredericton	13	26	33	5	15	19
Halifax	11	25	29	4	12	14
St. John's	7	17	21	2	7	10

As can be seen, right across the country, there is a direct relationship between orientation, the thermal efficiency of a dwelling, and the relative contribution of solar gain to total heating loads. The percent increase in heating loads for dwelling units not oriented south are consistently greater in super-insulated houses than in code houses built according to 1978 and 1984 standards. For super-insulated houses, the percent increase in heating loads for units oriented north instead of south, ranged from 21 to 45%. For super-insulated houses facing east or west, the percent increase in heating loads ranged from 10 to 27%. The implication is that as increasingly energy efficient houses continue to be built in the future, passive solar design has the potential to contribute a correspondingly greater percentage of overall residential heating loads.

Typically, the annual solar contribution of a passive solar house is in the range of 25-40%.[65] This solar gain is usually accomplished using some combination of: solar collection; heat distribution; storage; and energy conservation.

The objective with respect to solar collection in the house is to select the right type of glazing, with the right orientation and area, in order to maximize energy savings. Although a south facing window admits energy to a house, it also allows heat to escape. Passive solar designs must employ glazings and window orientations that ensure a net heat gain. If there is adequate heat circulation and thermal storage to accommodate solar gains, a window that provides a net heat gain to a building performs better than a well insulated wall.

Since only part of the heat admitted to a building can be used immediately, the remainder must be circulated throughout the house or stored for later use. Passive solar houses, therefore, are designed for good heat distribution and natural air circulation. Fans and blowers are often part of the design.

Thermal storage, an integral part of every passive solar house, can be provided by conventional building materials, such as plasterboard and plywood, or, ideally, by heavy building materials, such as masonry, concrete block, tile and double layers of plasterboard.

A final element, landscaping, which focuses on creating desirable micro-climates, can also contribute to passive solar design. The presence of trees and hedges acting as windscreens, for example, have been observed to reduce wind velocities by as much as 30-50%.[66] Other studies suggest that dense pine, capable of reducing wind speeds by up to 85% for a distance of 12 metres leeward, will decrease air infiltration by some 40%.[67] Generally, an ideal energy plan would develop coniferous buffer plantings to the north to screen cold winter winds, and deciduous plantings to the south to shade surfaces and south-facing walls in the summer, while allowing sun penetration in the winter.

Generally, much of the art of passive solar design involves finding the right balance between glazing type, size and location, thermal storage, and air circulation. A passive solar system will not function effectively, however, unless the house is built to contain the collected heat. Conservation levels, such as those required to meet the R-2000 standard should be employed.

3.11 Healthy Housing

In 1991-92, CMHC sponsored a Healthy Housing Design Competition in an effort to respond to the various housing and community issues described above. The purpose of the competition was to develop house designs that are "healthy" for both the occupants and the global environment. Competitors were encouraged to propose innovative and integrated solutions to a broad range of design criteria, including: occupant health; energy efficiency; resource efficiency; environmental responsibility; and affordability.

The three categories of houses included in the competition were: suburban detached; retrofit of a typical older home; and low-rise urban infill. The two winning designs were both infill houses, reflecting the importance of residential solutions which reduce urban sprawl (and hence transportation energy requirements) and make better use of existing infrastructure and other urban amenities. One of the winning designs, scheduled to be built in Toronto in 1993, is a completely autonomous house, capable of functioning independent of urban energy, water and wastewater infrastructure. The proposal aims to build a three-storey dwelling on an area not much larger than would be occupied by a two-car garage. The house does not make use of the energy grid, but combines passive solar gain with a wood heater for space heating, and photovoltaics for electrical generation. Free of water supply and treatment infrastructure, the house also includes a rainwater recovery system; two purification systems; a grey water recycling system; an organic waste composting tank; and ultra low-flow plumbing fixtures, including a toilet that requires only one cup of water per flush. Total construction cost of the house is estimated to be under $120,000.

The other winning infill design focused on improving indoor air quality as well as protecting the natural environment. Scheduled to be demonstrated in Vancouver in 1993, the design aims for: a 15% reduction in framing lumber compared to conventional construction; as much as a 60% reduction in the embodied energy used in the manufacturing of construction materials compared to conventional construction materials; a 46% reduction in space heating energy requirements; and a significant reduction in electrical power consumption by using high efficiency appliances and by substituting daylighting for electrical lighting.

High indoor air quality is to be ensured by using low off gassing finishes throughout the house; a high efficiency ventilation system that distributes fresh air to all areas of the home; multiple filtration in the heating system; and thoroughly sealed ductwork to prevent air pollutants from leaking into the home.

The unit was designed to satisfy the housing needs of various growing segments of the Canadian population, including single parent families, first time home buyers, and retired couples. Total construction cost of the house is estimated to be under $115,000.

4.0 CONCLUSION

This paper reviewed the environmental impacts associated with today's housing developments and discussed some of the strategies that can help reduce these impacts. For example, careful attention to integrated energy systems, construction methods, and building materials, can help reduce the operating energy requirements of our homes. Similarly, in subdivision design and site selection and planning, the degree of consideration given to topography, vegetation and exposure to the elements, can significantly exacerbate or diminish energy requirements for space heating and cooling.

Household water use can be greatly influenced through the user-pay principle. Urban intensification, usually involving a denser, more diversified mix of residential, commercial and other land uses, can make better use of existing infrastructure and municipal services, and tends to reduce space heating requirements. It can also lower average transportation energy requirements by reducing the frequency and distance of automobile travel, and by enhancing the opportunities for public transit, walking and cycling. In addition, compact contiguous development patterns facilitate the protection of agricultural land, parkland, wetlands, wildlife habitat, and other environmentally sensitive areas. Water collection costs are also greatly reduced in clustered and more dense developments, and treatment costs are lower with larger treatment plants.

For over a decade, CMHC has been investigating the feasibility of applying these and other environmentally-responsible solutions in the residential sector. The majority of the solutions have already proven to be technically feasible. One of the major challenges that remains therefore, is to inform municipalities, home builders and home buyers of the overall social, economic and environmental costs of today's development patterns. They must also understand the many advantages that today's new building practices and innovative approaches to community planning have in terms of increasing housing flexibility and choice, enhancing housing affordability, and reducing the overall energy and resource intensity of our living environments.

In order to make more informed decisions, home buyers have to be made more aware of the various social, economic and environmental tradeoffs that they make when they choose what kind of house to buy and where. This information will also help offset some of the "Not-In-My-Backyard", or "NIMBY" syndrome that typically accompanies redevelopment plans in existing communities. Municipalities, in turn, must encourage more innovative housing solutions that better respond to today's environmental challenges and to rapidly changing demographic and socio-economic conditions. Of particular importance in this respect is the need to reform certain municipal land use and site servicing standards, which are often seen as being excessive, outdated and overly rigid, thereby preventing the use of new technologies, and innovative cost-saving approaches to community planning and design.

Ultimately, a more flexible regulatory environment, along with a more informed public, will make it easier for home builders to respond to today's changing housing needs by supplying homes that are at once more affordable, more adaptable, more energy and resource efficient, and healthier for the occupants.

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