

# THREE DECADES OF INNOVATION

In Housing Technology  
1966 - 1996



HOME TO CANADIANS  
Canada

# CMHC—HOME TO CANADIANS

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***Three Decades of  
Innovation in  
Housing Technology: 1966-1996***

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# EXECUTIVE SUMMARY

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The 50 years following the end of World War II were a remarkable time of growth and change for Canada's housing industry. Three quarters of the housing stock was built during this period. Innovation—in technology, design and planning, and in policy and financing—has been the key factor which allowed Canadian housing to meet increased performance and production demands.

*Two Decades of Innovation in Housing Technology: 1946-1965*, published in 1994, chronicled the innovations which emerged in response to the postwar building boom. This report, *Three Decades of Innovation in Housing Technology: 1966-1996*, continues the story, highlighting the many advances which took place to address rising costs, energy and environmental impacts, occupant health and safety, durability and new niche markets.

## The Context

The period from 1966 to 1996 was characterized by the continued and often rapid growth of Canadian cities, the impact of the baby boom generation on housing markets and fluctuating economic cycles. Consumer preferences for homeownership and for detached dwellings remained strong, although the growing number of elderly Canadians and smaller households created specialized new markets. Interest in rehabilitating the existing stock led to renovation activity overtaking new construction in expenditure volume. Building codes and the development approvals process became more demanding. Federal and provincial housing policy evolved from being highly interventionist to being more targeted and market-sensitive.

## Innovations in Planning and Design

Planning was initially dominated by the explosive growth of both low-density suburbs and high-density apartments. Rising land costs led to innovations in lot usage and many experiments in medium-density housing. Urban renewal was superseded by neighbourhood upgrading and infill. The concept of sustainable development began to influence planning principles.

The design of housing units was characterized by a general increase in size and amenities, smaller frontages and a shift from modern to more traditional appearances. Changing lifestyles influenced the use of space in the home. Barrier-free accessibility emerged. The renovation boom transformed and expanded many older dwellings.

## **Innovations in Productivity**

After the dramatic reductions in on-site labour during the two decades following World War II, there were fewer production changes in low-rise housing during the next 30 years. Larger builders developed their own prefabrication facilities, but such operations disappeared by the 1980s, due to various factors, particularly fluctuating demand and regulatory obstacles. Similar factors prevented manufactured housing from maintaining the increased market share achieved in the early '70s. Site building continued to dominate and was further streamlined by greater reliance on factory-assembled components and sophisticated power tools and equipment.

Apartment construction experienced a revolution in the 1960s. The introduction of new crane technology, particularly tower cranes, plus flying formwork, flat slab construction methods and workers' hoists allowed for economical increases in height.

## **Innovations in Performance**

Much of the innovation and supporting research focussed on improving the performance of Canadian housing.

The most significant influence was the energy crisis of the mid-1970s, which prompted the development of air leakage control, advanced framing for increased insulation levels, heat recovery ventilators, high-performance windows and high-efficiency heating and lighting systems. The search for alternative energy sources led to passive solar and earth energy systems, plus niche market applications for photovoltaics and solar hot water heating. The R-2000 Program, launched in 1982, provided a focus for energy-efficiency demonstrations, research and training.

The later thrust toward sustainable housing pushed beyond energy to address other environmental impacts of housing and led to innovations in water conserving fixtures, chlorofluorocarbon (CFC)-free technologies, construction waste management and materials with high recycled content. Key demonstration programs included Healthy Housing and Advanced Houses in the low-rise sector and the IDEAS Challenge in the high-rise sector.

The response to the energy crisis raised concerns in two other areas—indoor air quality and moisture-related deterioration—leading to considerable building science research and information transfer to the industry. Two key conclusions were the need for source control, both for indoor pollutants and moisture, and the need for a “systems” approach, which considered the interactions among all house components.

Innovations contributing to healthier indoor environments included the emergence of low-emission building materials, spillage-resistant combustion equipment, more effective mechanical ventilation and filtration systems, and radon and lead mitigation techniques. Housing demonstrations for the environmentally hypersensitive showed that it was possible to eliminate most pollutants from the indoor air.

Research into moisture problems in low-rise housing led to the development of construction practices which minimized the exfiltration of moisture into the building envelope, kept water away from basements and optimized the drying potential of walls. Durability research also focussed on reducing high-rise cladding failures, especially those associated with brick veneer on steel stud backup, and on cost-effective methods of preventing concrete deterioration and restoring failed concrete in parking garages.

After much experimentation, housing agencies and builders adopted successful approaches to construction in northern and remote areas, emphasizing stable foundations and durable building envelopes. New technologies assisted the elderly and people with a disability to live independently. Other areas of innovation included fire prevention, noise control and infrastructure renewal.

The upgrading of the existing stock spawned innovations in energy-efficiency retrofits and in the replacement of major components, such as windows, claddings and heating systems.

As a result of these many innovations, Canadian housing has become more energy efficient, environmentally responsible, healthier for its occupants and durable, while still remaining affordable to most Canadians. These accomplishments have also created opportunities for many Canadian construction systems—both low-rise and high-rise—to expand into export markets.

## **Major Players**

The key organizations during this period undertook and encouraged innovation. The federal government's housing agency, Canada Mortgage and Housing Corporation (CMHC, renamed from Central Mortgage and Housing Corporation), pursued a wealth of technical research and information transfer activities, spearheaded numerous design and planning innovations and undertook many groundbreaking demonstrations. The Canadian Home Builders' Association (CHBA which evolved from the Housing and Urban Development Association of Canada and originally the National House Builders' Association), fostered industry-government collaborative approaches to innovation. The National Research Council's Institute for Research in Construction (NRC, IRC, renamed from the Division of Building Research),

continued to undertake supporting research, while Natural Resources Canada (NRCan, formerly Energy Mines and Resources Canada) provided the thrust toward more energy-efficient homes. CMHC's National Housing Research Committee and the CHBA's Technical Research Committee provided forums for interagency collaboration and initiative.



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# I. INTRODUCTION

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## Canada: “One of the Best-Housed Nations in the World”

Canadian housing has undergone a tremendous evolution in the latter half of the 20th century. Our housing—in comparison with most other Western nations—is spacious, well equipped, energy efficient and diversely suited to a range of lifestyles and climates, while remaining generally affordable to most of the population. As a result, Canada is often referred to as one of the best-housed nations in the world.

What has led to Canada’s success?

Innovation—in housing technology, design and planning, and in policy and financing—can be cited as the major factor which has allowed Canadians to overcome the serious challenges associated with:

- the postwar housing shortage;
- boom and bust economic cycles;
- major demographic and population shifts;
- rising costs for serviced land;
- shortages of skilled labour;
- fluctuating material and labour prices;
- energy and environmental constraints; and
- a generally severe climate.

In 1996, Canada Mortgage and Housing Corporation (CMHC) marked its 50th anniversary and the close of a half century of intensive innovation. During this remarkable period, more than three-quarters of the current Canadian housing stock was built, the Canadian housing industry took shape and matured, federal and provincial housing policies became increasingly sophisticated and construction materials, systems and methods were transformed.

While hundreds of reports have been published on the development of solutions to specific

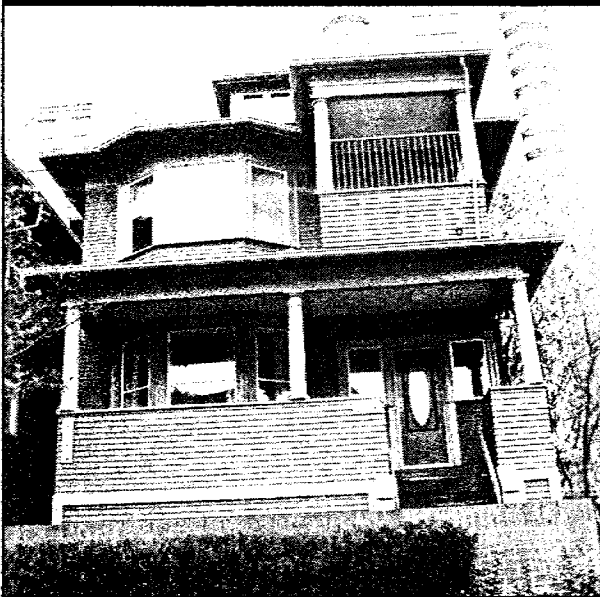
technical challenges, very little has been written about the overall evolution of Canadian housing technology and the remarkable advances that have been made. It’s a story worth telling.

## The First Two Decades

In 1994, CMHC published the document *Two Decades of Innovation in Housing Technology: 1946-1965* [1], which traced the exciting technology developments in the postwar years. That period from 1946 to 1965 was characterized by a rapid expansion of Canada’s housing production capability in response to the postwar housing shortage and the subsequent economic growth and baby boom of the ’50s and ’60s.

Many new construction methods were adopted, lowering costs and reducing the average on-site labour per home from 2,400 to 950 hours. Low-rise wood frame construction evolved from labour-intensive site work to the greater use of prefabrication and composite materials. Plywood replaced board sheathing; roof trusses replaced rafters; gypsum board replaced plaster; poured concrete gained precedence over masonry foundations; components such as windows, cabinets and stairs were increasingly prefabricated off site. New products, such as aluminum and hardboard siding, plastic foam insulations, stressed-skin panels and polyethylene vapour barriers, were introduced. Occupant comfort was improved through better-insulated walls and ceilings, double-glazed sealed windows, forced air furnaces, wall-to-wall carpeting and electric baseboard heating, and the development of dryer, more habitable basements. High-rise apartments began to emerge as an economic form of urban housing. Increasing mechanization, particularly excavation equipment, also reduced labour costs. The development of cold weather construction techniques made house building a year-round business.

**Photo 1:**  
**In low-rise or high-rise, Canadians are one of the best housed nations in the world**



During the first two decades, Canada's research community began its study of building science in earnest, focussing on air, heat and moisture flows. This led to improved standards and materials for windows, heating systems, insulation and moisture control. Also, the groundwork for future technology changes was laid through research and the demonstration of new technologies such as preserved wood foundations, self-contained sewage systems, plastic plumbing and air leakage testing. Particularly noteworthy as demonstrations during this period were the first four Mark projects, prototype houses developed by CMHC, the National House Builders' Association (NHBA) and the National Research Council's (NRC's) Division of Building Research (DBR) to test innovative, low-cost construction materials and techniques.

Accompanying this major shift from traditional construction methods was the widespread adoption of new forms of community planning and house design. Postwar suburbs were based on "garden city" principles (an idea developed in England by Ebenezer Howard at the beginning of the 20th century which advocated small "green" towns as an alternative to the dirty congested

industrial cities and the depressed depopulated countryside) with curvilinear streets and low densities. Ranch-style bungalows with open plans and low profiles dominated, complemented later by two-storey and split-level designs. Apartments evolved from mid-rise to high-rise. Zoning by-laws became common and the fledgling planning profession expanded. CMHC's plans service fostered modest, affordable houses, particularly the storey-and-a-half design prevalent immediately after World War II. New communities sprang up in the north and outside urban areas.

There were three major players.

- Central Mortgage and Housing Corporation, which was created in 1946, took a major role in the direct design and delivery of postwar housing, in providing national standards and a materials evaluation service, and in sponsoring research and demonstrations.
- The National Research Council's Division of Building Research, which was created in 1947, undertook technical research in support of CMHC, the National Building Code and the industry.
- The National House Builders' Association, which was created in 1943, represented the building industry and provided linkages between private builders and government agencies, and established the Technical Research Committee in the mid-1950s.

## The Unfolding Story

This publication continues the story begun in *Two Decades* and outlines the ongoing development of Canadian housing technology over the three decades from 1966 to 1996. This 30-year period saw the further evolution of cost-effective building techniques, the development of world-leading expertise in energy efficiency and building science, experiments in denser housing forms, the emergence of the renovation industry and an explosion of new

products in response to increasing performance and environmental demands. While the first two postwar decades were notable for innovation in housing *production*, the following three decades were most innovative in improving house *performance*.

Parts I and II of this report provide the context for technology development during the 1966 to 1996 period. Part I outlines the background factors which have shaped Canadian housing, such as population trends, economic cycles, world events, consumer attitudes and lifestyles, the changing role of governments and the evolution of the housing industry. Part II contributes additional context with an overview of the significant changes in urban planning and in the design of housing units, along with the underlying factors causing these changes.

Parts III and IV capture the key technology innovations, which occurred during this 30-year period. Part III traces the development of productivity improvements in the industry, both on the construction site and in the plant, for low-rise and high-rise construction and also for renovation. Part IV highlights technical advances in specific areas such as energy efficiency, durability and the indoor environment.

## Sources and Methodology

*Three Decades of Innovation in Housing Technology: 1966-1996* was researched and written for CMHC's Technical Policy and Research Division by Scanada Consultants Ltd. The team consisted of Terry Robinson, Robert Platts, Kevin Lee and Nicola Rutherford, with assistance from Linden Holmen of Clayton Research Associates Ltd. and Marc Denhez.

Numerous information sources were drawn on in assembling material for this report, including CMHC advisory documents and research reports, CHBA and NRC publications, minutes of CHBA's Technical Research Committee, trade magazines and the team's own resource files.

Particular credit must be given to three sources.

- The first is Marc Denhez's 1994 book, *The Canadian Home: From Cave to Electronic Cocoon* [2], which presents a comprehensive, and often humorous, account of the politics and attitudes surrounding the development of housing in Canada. Denhez's publication was particularly useful in developing the context sections on the Canadian housing scene and on design and planning.
- The second source is the CMHC series, *The Housing Industry: Perspective and Prospective*, which was developed by Clayton Research Associates and Scanada Consultants in the late 1980s. In particular, *Working Paper Two: The Evolution of the Housing Production Process 1946-86* [3], along with the interviews undertaken at that time, served as a major resource for the section on housing production.
- The third reference—the research compendiums and bibliographies prepared by CMHC's Canadian Housing Information Centre (CHIC)—served as an invaluable checklist in summarizing the great extent of technological developments for the section on housing performance. The Centre's photo and slide library was also the major source for the photographs, which accompany the text.

Acknowledgment must also be given to Paula Archer and Brian Eames, both of CMHC's Research Department. The former was CMHC's original project manager for the text, while the latter obtained the illustrations and coordinated final editing and production.

The development of *Three Decades* was able to draw on a far greater wealth of documentation than was possible for the earlier period covered in *Two Decades* and, therefore, has been written in a somewhat different tone, relying less on interviews and anecdotes.

## ***PART I***

### ***THE CANADIAN HOUSING SCENE***



## 2. THE MAJOR FACTORS AFFECTING CANADIAN HOUSING

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The mid-1960s to the mid-1990s was a time of significant demographic change and major economic boom-and-bust cycles in Canada. Global issues, such as energy supply and environmental concern, also impacted Canadian housing. It was a period of ongoing evolution of the housing industry. Perhaps most important, these three decades were characterized by intensive debate on housing policy, marked by considerable federal intervention in the housing markets in the 1970s and eventually leading to redefined roles for federal and provincial governments.

This section provides an overview of the factors influencing Canadian housing from 1966 to 1996. It attempts to set the context for the technology innovations which occurred rather than presenting a detailed analysis of housing policy or of housing industry activity during that period.

### Population and Demographic Trends

#### Urban growth

Canada's population grew by 50 per cent from 19.5 million in 1965 to almost 30 million in 1995 [1]. Most of this growth occurred in urban areas. The postwar population shift from rural areas to major cities continued, primarily due to the ongoing transformation of the Canadian economy from a resource base to a service and information base. Urban growth was also fuelled by immigration patterns, with newer immigrants seeking employment opportunities in cities in contrast to the prewar waves of immigrants who sought land for farming in rural areas. This growth led to a massive expansion of Canadian suburbs and the need to extend existing infrastructure.

#### Changing demographics

Canada's baby boom generation—proportionately the largest of any Western country—began entering the housing market in the late '60s and '70s, initially as singles desiring their own apartments and, increasingly through the '70s

and '80s, as young families seeking a first home or renovating an older dwelling. This led to successive peaks in apartment construction, suburban developments and renovation.

Canada's population was also ageing. At the beginning of this period, only eight per cent of Canadians were over 65, while by the mid-1990s, this had increased to 12 per cent and was forecast to double to 25 per cent by the year 2031 [2]. Wealthier and healthier than past generations of seniors, Canada's greying population created a demand for luxury condos, affordable rental apartments and more accessible unit designs for "independent living".

Household size shrank from an average of 3.8 to 2.8 from 1961 to 1991 [1, 3] as Canadians had fewer children. The number of lone-parent households tripled, increasing the demand for modest, affordable urban housing. By the end of this period, the coming of age of the "baby bust" generation—fewer in numbers than the boomers—combined with reduced levels of immigration to result in less demand for new housing.

### The Economy

#### Economic cycles

Unlike the steady growth that characterized the first two decades after World War II, the mid-1960s to mid-1990s experienced a roller coaster economy. In the late '60s, urban growth and the exodus of baby boomers from their parents' homes fuelled an explosion of apartment construction, with the number of apartment starts tripling over the decade. These years were also marked by spiralling construction costs. Urban growth—particularly in the suburbs—was even more frantic in the early and mid-1970s, with the highest number of annual housing starts in Canadian history being recorded. In 1976, total starts were 273,000 and single-family starts were 184,000.

Global energy trends intruded on Canadian housing markets unexpectedly in the 1970s. The Organization of Petroleum Exporting Countries (OPEC) energy crisis, initiated in 1973, led to temporary shortages of certain products, a rapid shift in fuel use from oil to natural gas and electricity, changes to energy-efficient construction practices and, in response to various government subsidy programs, the birth of the energy retrofit industry.

In the late '70s and early '80s, the Bank of Canada's high interest rate policy to combat inflation reduced housing affordability. In 1981, mortgage rates ran as high as 22 per cent, and the carrying costs for a typical home increased by a third [4]. The recession of the early 1980s caused new housing starts to tumble, reaching a low of 126,000 in 1982. After more than a decade of massive expansion, the housing industry suffered considerable attrition, losing many builders. In Ontario, for example, 30 per cent of builders went out of business. The survivors switched from speculative building to pre-selling. The crash in Alberta—exacerbated by a fall in world oil prices—was particularly severe, with vacancy rates in excess of 10 per cent and widespread mortgage defaults. Falling energy prices also spelled an end to some energy-efficiency initiatives.

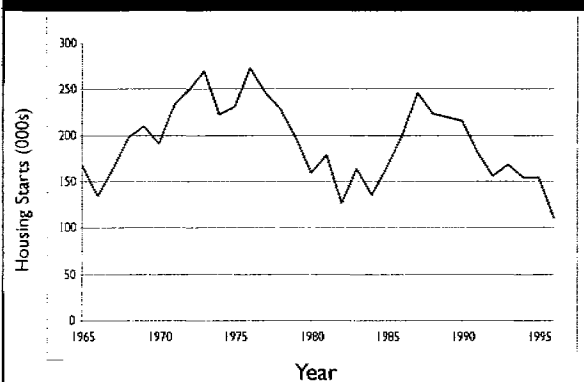
Renovation activity, however, continued to rise and in the early '80s surpassed new housing in financial volume. The renovation boom had begun in the late '70s, driven largely by yuppies—young urban professionals seeking an alternative to the suburbs.

While housing starts remained modest in the Prairies and Atlantic Canada throughout the 1980s, an economic recovery fuelled an unprecedented housing boom and price spiral in central Canada and British Columbia in the mid and late '80s, particularly in the metropolitan Toronto and Vancouver areas. New housing activity, with starts of 246,000 in 1987, again surpassed renovations, although only temporarily. Affordability reached crisis proportions in overheated markets. There were severe shortages

of labour and materials, causing completion dates to be extended and a high rate of buyer dissatisfaction with construction quality.

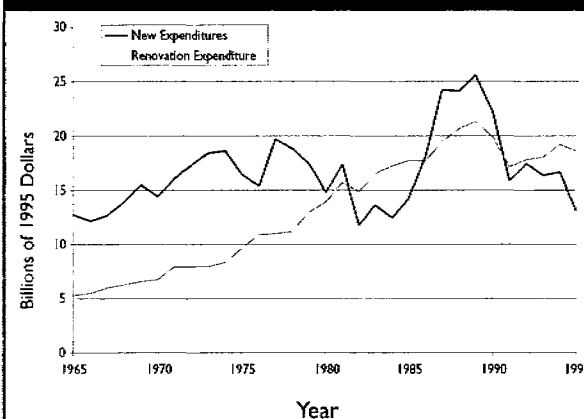
The late '80s and early '90s were also marked by the re-emergence of energy as an economic issue. Energy retrofits were spurred by the demand-side management activities of electrical utilities, which were unable to finance further expansion of their energy supply capability. The linkages being drawn between the economy and the global environment—particularly after the United Nations' 1987 release of the Brundtland Commission report, *Our Common Future* [5]—also sparked interest in more sustainable forms of housing and communities.

**Figure 1:**  
**Annual Housing Starts: 1966 to 1995**



Source: CMHC [1.5]

**Figure 2:**  
**Annual Housing Expenditures:  
New Construction vs. Renovation**



Source: Clayton [6] and CMHC [5.7]

In contrast to the economic expansion of the '60s, '70s and late '80s, the 1990s presented some sobering realities. An extended recession, followed by a "jobless recovery", was marked by deflationary trends in housing, a large spread between interest rates and inflation, and a general loss of consumer confidence due to concern over job security and rising government debt. By the mid-1990s, the implementation of expenditure cuts in all areas, including housing, had begun at all levels of federal, provincial and municipal government. New housing starts fell to about 100,000 and even the renovation market was dampened.

### **Growing (and declining) affluence**

Most Canadians enjoyed significant increases in personal income in the 1960s and '70s. This growing affluence, combined with the increasing proportion of families with two incomes, fuelled higher housing expectations, not only for homeownership but also for larger, better equipped homes, filled with greater quantities of possessions.

However, for many seniors, lone parents and others earning minimum wages or on fixed incomes, the high inflation rates and escalating housing costs—particularly during the 1970s and again in the late 1980s—meant a widening gap in affordability. Social housing policies and programs took on great importance and are discussed in further detail later in this section.

By the 1990s, real incomes were declining. The often quoted rule of thumb was that the lifestyle that could be afforded on one income in the 1950s was requiring two incomes in the 1990s. While this was an exaggeration, it was true that the net result of various economic factors—inflation, higher wages, more two-income families, higher housing costs and larger houses—meant that the percentage of family income spent for housing was about the same in the mid-1990s as it was in the 1950s [4]. In the closing years of the 20th century, the prospects for future homebuying generations (Generation X) appeared considerably bleaker

than for the previous baby boom generation due to the lack of secure employment opportunities.

### **The Sociopolitical Climate**

The 1960s and '70s were characterized by the "flower power" empowerment of youth, liberal attitudes toward lifestyle (e.g., the "sexual revolution"), continued optimism toward the future and a desire to bring about social change. The term "just society" was popularized by the federal Liberal Party, which was in power through much of this period. This was a time of many experiments in housing design and urban development. It was also a time of considerable federal government intervention in the housing market.

After the economic ups and downs of the 1980s and the growing realization of the impact of accumulated government debt, Canadian attitudes had shifted by the early '90s and could be characterized as insecure and conservative. Society had become polarized on numerous issues from welfare to gay rights to the death penalty. The explosion of personal computers, sophisticated telecommunications and the information highway was revolutionizing both business and home life, but was also contributing to higher stress levels. Canadians were increasingly introspective, "cocooning" themselves in their homes to escape a hostile world. There was no longer much belief that societal problems could be solved by big government programs, and there was increasing reliance on the private sector and on private-public collaboration.

Some of the sociopolitical trends of particular relevance to Canadian housing included the following.

### **Preference for homeownership**

Despite (or perhaps because of) escalating housing costs, Canadians' desire for homeownership remained as strong as ever. Inspired by their parents' apparent windfalls (e.g., the \$13,000 bungalow purchased in

1955 selling in the late '70s for over \$100,000), prospective homebuyers often felt compelled to extend themselves to their financial limits to acquire a house which they felt would be even further out of reach next year. Even in the 1990s, when housing was not as attractive an investment as it had been in the past, Canadians, including three quarters of renters [9], remained wedded to the dream of ownership. For smaller or less affluent households, the import of the condominium ownership concept from Europe and the United States in the 1970s meant that many traditional renters could become owners. The collapse of the condo market in the recession of the early '80s, combined with ongoing complaints about high condo fees, meant that condominium ownership was no longer as attractive, but was still successful in niche markets.

#### **Preference for detached dwellings**

Canadians' preference for the suburban dream—a single-family detached home—remained strong during this period and was encouraged by the housing and real estate industries' marketing. While numerous alternative housing forms were introduced, particularly in the '70s, and despite considerable efforts on CMHC's part to promote well-designed, medium-density projects, detached

homes were seen as offering better-quality, higher resale value, greater acoustic and visual privacy, and enhanced social status. Multiple housing continued to be perceived by most Canadians as an entry point into the housing market rather than as a final goal.

#### **Rent controls**

Initiated by British Columbia in 1974, rent controls of various forms were in place in all provinces by 1976 as an anti-inflation measure. While they did keep rental accommodation more affordable, they also were a significant disincentive to new construction.

#### **Changing attitudes toward social housing and affordability**

The public housing of the '50s and '60s, often austere in appearance and clearly identifiable as low-income housing, was gradually replaced by attractively designed medium-density social housing developments in the '70s and '80s.

**Photo 2:**  
Canadians remain strongly committed to the "suburban dream" of a single-family home on a large, quiet, and well treed lot  
*Photo courtesy Oliver Drerup*



**Photo 3:**  
Attractive medium-density social housing developments in the '70s replaced the large, austere public housing projects which dominated the '50s and '60s



Federal and provincial social housing policies sought to integrate such housing more successfully into the community by mixing subsidized and non-subsidized tenants, demonstrating innovative and improved design and construction, and

encouraging partnership approaches often led by non-profit agencies. The design results were impressive, but the costs were high and the number of Canadians in need of housing assistance continued to increase. The year 1985 marked a watershed. The Nielsen Task Force clearly indicated that the priority for social housing must be on housing those in greatest need [10], while the Consultation Paper on Housing [11] ushered in a new era of collaboration between the federal government and the many other actors in the housing field. Social housing became leaner, particularly with the freeze on expenditures in the early '90s, and was increasingly led by the provincial housing ministries.

### **Public participation**

Citizens' movements emerged in the '60s and early '70s to stop the destruction of existing neighbourhoods in response to the continued postwar policy of slum clearance for urban renewal. This evolved into formalized public participation processes in the '70s, as exemplified by CMHC's LeBreton Flats redevelopment in Ottawa. While such public empowerment served as a check against the excesses of governments and developers, it could also prove to be self-serving, leading to the "not in my backyard" syndrome which blocked the development of affordable housing or needed infrastructure.

### **Interest in preservation and renovation**

For various reasons—less concentration of urban poverty, fewer racial tensions, a more effective social safety net, more recently built urban infrastructure and buildings, and the existence of various improvement programs—Canadian cities generally did not follow the American pattern of deterioration and instead experienced a revitalization. The post-war love for urban renewal and "modern" housing was gradually replaced by a growing distaste for the resulting checkerboard of high-rises and parking lots. Interest increased in preserving the existing urban fabric, restoring architectural heritage and recycling the traditional housing stock. Starting with the "whitepainters" (those who merely painted over the problems of run-down properties and resold them for a fast profit)

who rediscovered downtown living in the early '70s and, aided by the energy crisis which exploded the myth of limitless resources, renovation activity blossomed in the late '70s and early '80s. From representing only 25 per cent of new construction expenditures in 1970, renovation expenditures surpassed new construction in the early '80s. Factors encouraging renovation included the ageing housing stock, the ageing population, the revitalization of urban cores and the high costs of new housing. Municipalities increasingly recognized that renovation added more to the net tax base than new construction, since renovation generally did not require additional transportation or underground infrastructure.

### **Environmental concern**

Interest in conservation grew in the '60s as part of the counterculture movement and in response to authors such as Rachel Carson, Jane Jacobs and the Club of Rome, who sounded the alarm at the projected impacts of unbridled urban growth and resource consumption. Conservation activities, which had exploded in the '70s in the wake of the energy crisis, declined in the '80s with the fall of world oil prices before re-emerging after the release of the U.N.'s Brundtland Commission report in 1987. Activities declined again in the face of hard economic times in the 1990s. Despite the ups and downs, energy and environmental issues became firmly entrenched as a determinant of Canadian housing and are discussed in detail in Part IV in relation to technology advances.

## **The Regulatory Environment**

The period from 1966 to 1996 was characterized by steadily increasing regulatory demands on housing, aimed at raising its quality, increasing its energy performance, improving health and safety, and reducing environmental hazards.

### **Building codes and by-laws**

The National Building Code (NBC) and provincial building codes continued to evolve, becoming increasingly sophisticated and comprehensive. Requirements for mechanical

ventilation, combustion venting and air barriers proved to be controversial issues in the '80s, but were firmly entrenched in building codes by the mid-1990s. The large number of ongoing code changes raised industry concerns regarding the impacts on affordability, particularly in Ontario after the substantial 1993 revisions to the Ontario Building Code, and the roll back of some requirements in the 1997 Code.

In terms of the impact on innovation, while the NBC and provincial codes clearly allowed equivalencies, local building officials were often averse to accepting alternate approaches due to the liabilities involved [12]. This was one of the factors leading to investigations of performance-based approaches, particularly for renovation activities [13].

In the wake of the 1970s energy crisis, provincial codes began adopting energy conservation requirements, often based on the Measures for Energy Conservation in New Buildings developed by the NRC in 1978. The largest impacts on building practice were not felt until the '80s and '90s, with provincial code changes resulting in typical new housing being more than 30 per cent more energy efficient in 1995 than in 1980 [14]. In the early '90s, the National Energy Code for Housing was developed, based on a life-cycle cost approach and tailored to provincial energy costs. This model code was scheduled for release in 1996, but faced an uncertain future due to resistance from the industry and some provincial governments.

Municipal by-laws also influenced new housing. Some communities wished to ensure a certain quality of development (e.g., minimum floor area or "earth tone" exterior requirements). In the '90s, several municipalities enacted requirements for fire sprinklers in low-rise housing.

As municipalities gradually withdrew from directly servicing land in the 1970s and transferred this responsibility to developers, there was a tendency to increase servicing standards, such as road allowances, lighting and sewers. This contributed to higher costs for serviced lots.

### **Product approval, labelling and guidelines**

The materials evaluation process, which had been extremely influential both on new housing financed through provisions of the *National Housing Act* (NHA) and on the remainder of the new stock, passed from CMHC's Materials Evaluation Service to the NRC's Canadian Construction Materials Centre in 1988.

Product labelling became increasingly important as a complement to regulation. In the 1980s, Energy Mines and Resources' (EMR's) Energuide labels began to identify the efficiency of appliances and equipment. In the '90s, a sophisticated, made in Canada window rating system was implemented, Environment Canada's EcoLogo began appearing on a wide range of building materials, and steps were taken to develop a national home energy rating system.

Non-mandatory guidelines became influential in emerging areas, such as indoor air quality. Health and Welfare Canada's 1987 *Exposure Guidelines for Residential Indoor Air Quality* made Canada the first country to have such guidance, and these guidelines quickly became the de facto standard for surveys and research studies.

### **Planning approval**

At the level of housing developments, the planning approval process became increasingly long and onerous. Approval for rezoning and other variances from official plans was fraught with delays. Environmental assessment legislation, both federal and provincial, required some new developments to be modified or even blocked, particularly where prime agricultural land or wetlands were involved. The trend toward urban intensification, which often meant reusing former industrial or transportation lands, raised concerns over contaminated soils. In response, CMHC began requiring environmental site assessments by the early '90s.

In response to increasing recognition that regulatory delays were causing higher housing costs and restricting innovation, the Affordability and Choice Today (A-C-T) Program was launched in 1990 by CMHC, the CHBA, the Canadian

Housing Renewal Association and the Federation of Canadian Municipalities to promote regulatory reform through demonstrations and studies. A-C-T also encouraged the development of alternate land use standards which were less consuming of land and resources.

**Photo 4:**  
This Affordability and Choice Today (A-C-T) project in Montreal, Quebec demonstrated that better rooming houses could result from changes to municipal regulations



### **Regulatory and financial influences on multi-family developments**

Rent controls contributed to the drop in multi-family construction after the apartment boom of the 1960s. This was partially offset in the mid-1970s by the MURB (multi-unit residential building) tax shelters. The on-again, off-again deductibility of interest on financing land assembly affected the rate at which serviced land was made available to the market.

### **Metrification**

The federal government made the decision to convert to the metric system in the mid-1970s, although it took several years for this to be phased in. Commercial and apartment construction was virtually converted by the early '80s, but low-rise, wood-frame construction retained imperial measurements, largely because the size of the U.S. export market for wood

and plywood meant that these products continued to be manufactured in imperial sizes. Metrification had been touted as an opportunity to rationalize product sizes, but this was only realized to a minimal extent.

## **Evolution of the Canadian Housing Industry**

Canada's housing industry remained highly fragmented, characterized by many small builders and subcontractors. In comparison with other industries, such as the automotive industry or the housing industries of other countries, such as Japan's, this fragmentation represented a challenge in terms of in-house research and development, training and economies of scale. However, it was also a strength, allowing the industry to expand and contract quickly in response to economic cycles and to adopt new technologies readily. In essence, it was the means of survival.

### **Low-rise housing**

The size of single-family builders varied immensely. The boom of the 1970s brought greater numbers of large builders into prominence, particularly in southern Ontario and Alberta. However, many of these subsequently disappeared or were considerably reduced in size after the 1981-82 recession. In the '80s and '90s, most were small, building fewer than 25 units per year, but the five per cent or so which were medium or large, built about half the total number of new homes. The nature of low-rise site building continued to favour medium and small builders. Attrition rates during economic downturns were very high. The industry maintained its regional differences, with variations in builder size, building practices, material use and house designs. The low-rise builder retained the unique position of combining the tasks of market analysis, land development, financing, design, construction and marketing under one hat.

The NHBA changed its name to the Housing and Urban Development Association of Canada (HUDAC) in 1971, reflecting the increasing

involvement in land and community development. HUDAC subsequently became the Canadian Home Builders' Association (CHBA) in 1984. Provincial and local associations were strong in most provinces, giving the CHBA a total base of 12,000 firms by the mid-1990s. The Association provinciale des constructeurs d'habitations du Québec (APCHQ) remained relatively autonomous and was the only association to administer a warranty program directly.

### **Renovation industry**

This period marked the birth of Canada's renovation industry, which was dominated by small entrepreneurs, many also performing numerous trade functions. The creation of CHBA's Canadian Renovators' Council in 1984, the emergence of active renovators' committees in many provinces and cities, and the birth of the Association for Preservation Technology helped to legitimize the industry and bring its concerns to the forefront. While conflicts remained between builders and renovators in some provinces, the renovation industry became increasingly recognized as an equal economic and technical partner. A growing number of new homebuilders took on renovation work to balance their work volumes, further blurring distinctions.

### **Manufactured housing**

While there was ongoing interest throughout this period in manufactured housing as a solution to affordability, the predicted expansion of this sector never materialized. Mobile homes did enjoy an increasing degree of popularity in the '60s and early '70s, but lost ground after the introduction of the Assisted Home Ownership Program (AHOP), which did not apply to mobile units [3]. In the 1980s, manufacturers began forging stronger links with site builders, as well as moving into niche markets. The modular and mobile home industry was represented by the Canadian Manufactured Housing Institute, while producers of panellized, pre-engineered, log and timber frame systems were represented by the Manufactured Housing Association of Canada.

### **Land and apartment development industry**

Unlike the homebuilding and renovation industries, land development and apartment construction were characterized by larger firms that had more in common with the commercial construction sector than with low-rise housing. The 1970s were the golden age for land developers, with a massive expansion of Canada's suburbs. Activity became increasingly concentrated at that time in a few large firms. The subsequent recessions in the early '80s and '90s, combined with the loss of interest deductibility on land investments, made the land development business much less profitable and more risky. Apartment developers, after the 1960s construction boom when more than 50 per cent of housing starts were apartments, saw a continual decline of their industry due to economic factors, including rent controls. The industry shifted from developer-held rental portfolios in the 1960s, to building for MURB tax shelter syndicates in the mid-1970s, to condominium construction in the late '70s and '80s [15]. The Canadian Institute of Public Real Estate Companies (CIPREC) was the major organization representing the development industry.

### **Industry issues**

Particularly in the 1980s and '90s, the CHBA's broad-based committees, such as the Technical Research Committee, the Economic Research Committee, the Manufacturers' Council, the National Training and Education Advisory Committee and the Canadian Renovators' Council, played an increasingly central role in raising issues and coordinating national activities. In addition to technical issues, the industry grappled with professionalism. HUDAC introduced a Canada-wide system of new home warranty programs in the mid-1970s, which was supported by CMHC's requirement that homes have warranty coverage to be eligible for NHA mortgage insurance. Training and education took on greater importance, with extensive technical training for homebuilders, particularly through CMHC's Builders' Workshop Series and NRCan's R-2000 Workshops, and with an emphasis on business skills for renovators, such as through CMHC's National Renovator Training Program.



The difficulty of retaining a permanent work force through economic fluctuations led to a lack of skilled labour during boom periods and resultant homebuyer dissatisfaction. Starting in the early '80s, the industry became more outspoken against government intervention in the marketplace. The growth of the underground economy, particularly after the introduction of the federal Goods and Services Tax (GST) in 1990 and especially in the renovation sector, became a significant concern. The renovation industry also criticized what it saw as inequitable treatment under the *Income Tax Act* and the National Building Code.

### Federal Government Policies and Programs

The mid-1960s to the mid-1990s will be remembered as an era of great debate and evolution in housing policy. While some policies and programs had minimal impact on housing technology, they served to shape the rate and type of housing growth. Others, such as energy conservation programs, directly influenced the course of new technologies.

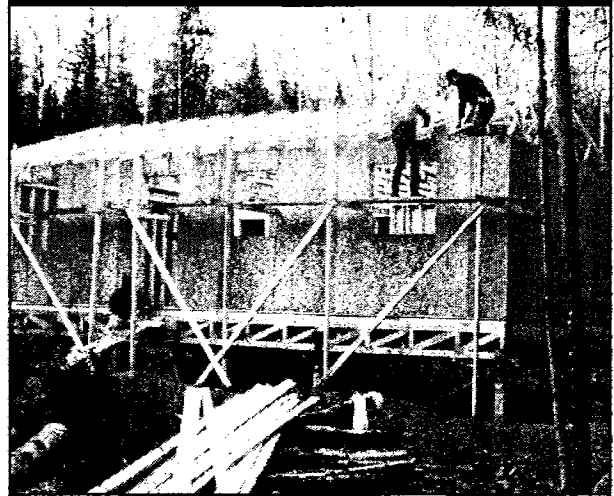
Central Mortgage and Housing Corporation, the federal government's housing agency, became Canada Mortgage and Housing Corporation in 1979.

Federal housing policy was highly interventionist through the '60s and '70s. At a time when budgets were plentiful, housing was seen as an instrument for economic growth and social change, and the federal government saw a strong role for itself in urban development. Characteristic of this was the creation of the short-lived Ministry of State for Urban Affairs in 1970, which was eventually absorbed by CMHC at the end of the decade. Through the '80s and '90s, social housing programs became leaner, more targeted and increasingly controlled by the provinces. Federal-provincial relations seesawed, becoming increasingly collaborative as resources shrank. Government-industry relations also became more cooperative and consultative.

### Public and social housing

By the mid-1960s, provincial housing agencies had been created and were increasingly interested in expanding their responsibilities. Central Mortgage and Housing Corporation, having been the country's largest developer immediately after World War II, reduced its direct construction activities and launched federal-provincial partnerships in public housing, plus non-profit and cooperative housing programs for low-income residents. In the early '70s, CMHC initiated the Rural and Native Housing (RNH) Program to assist residents in remote areas. By the late '70s, public housing programs were under increasing criticism for their high costs and "ghettoization" of low-income households. Programs were restructured to encourage a mix of subsidized and non-subsidized occupants. Greater emphasis was placed on the third sector—non-profit agencies—for delivery.

**Photo 5:**  
The introduction of CMHC's Rural and Native Housing (RNH) Program in the '70s brought housing assistance to residents in remote areas such as Long Body Creek, Manitoba



Federal-provincial agreements signed in 1986 provided for a variety of delivery strategies, with the provinces generally taking on a greater role [16]. The Rural and Native Demonstration Program in the late '80s provided a successful model for incorporating self-help construction. By the 1990s, CMHC and the provinces held

over 600,000 assisted housing units in diverse portfolios. Federal expenditures on social housing were close to \$2 billion annually and continually rising. The freeze and subsequent reductions in social housing spending in the '90s meant increased targeting to those in greatest need.

### **Market housing**

The federal government continued to pursue the goal of encouraging homeownership. CMHC's NHA mortgage insurance, which had been introduced in the 1950s, became an increasingly important element to Canadians in financing their dreams of homeownership, with approximately one third of all mortgages since World War II insured by CMHC. To maintain affordability in the face of escalating house prices in the 1970s, the AHOP provided loans and subsidies for moderately priced homes, assisting more than 150,000 new units from 1974-78. The Registered Home Ownership Savings Program (RHOSP) was also introduced to help first-time buyers save for a home purchase. During the same period, the Assisted Rental Program provided loans to builders of rental housing, assisting with 120,000 units, while special tax shelter provisions encouraged the development of 380,000 units in MURBs from 1974-1981.

**Photo 6:**

**The Assisted Home Ownership Program (AHOP) provided loans and subsidies for moderately priced homes such as this project in Windsor, Ontario**



During the economic downturn in Alberta in the early '80s, CMHC's Mortgage Insurance Fund and its holding of tens of thousands of defaulted properties prevented housing markets in the province from collapsing entirely. In the aftermath of the 1980s recession, the Canadian Home Ownership Stimulation Program (CHOSP) assisted 176,000 first-time homebuyers in 1982-83. This was augmented by similar provincial programs. These various programs also served to stimulate housing markets, causing temporary booms, which were invariably followed by downturns. Eventually, the housing industry lobbied successfully against such market interventions. In the 1990s, innovative financing options were made available, such as the Home Buyer's Plan, which allowed the use of registered retirement savings plan (RRSP) funds, and the First Home Loan Insurance Program, which lowered down payment requirements to five per cent for insured mortgages. The development of Mortgage-Backed Securities by CMHC served to increase available long-term mortgage funding in the market.

### **Urban renewal, home improvements and energy retrofits**

CMHC's Urban Renewal Program was used extensively by municipalities, but by the late 1960s was meeting increasing resistance from those wishing to preserve, rather than demolish, existing neighbourhoods. In the early '70s, to encourage the rehabilitation of the housing stock, CMHC launched the Neighbourhood Improvement Program (NIP) for municipalities and the Residential Rehabilitation Assistance Program (RRAP) for homeowners and landlords. RRAP continued into the '90s in various forms, including a program to facilitate conversions for disabled persons. The Rehabilitation Skills Training Centre was active in the early '80s in training RRAP inspectors, delivery agents and renovators.

In response to the 1970s energy crisis, several programs were launched to encourage energy retrofits of existing homes. The two most notable were the 1977-1987 Canadian Home Insulation Program (CHIP), administered by CMHC, and the

1980-85 Canadian Oil Substitution Program (COSP), administered by EMR.

A further incentive program in the early '80s was the Canadian Home Renovation Program (CHRP), which provided grants for contracted home improvements. While stimulating the renovation markets, these programs were also accused of encouraging fly-by-night contractors. Energy Mines and Resources was very active in the 1980s in delivering retrofit training. CMHC focussed on rehabilitating existing public and social housing, with landmark projects such as Regent Court in Regina and Uniacke Square in Halifax.

**Photo 7:**  
In the '80s, CMHC focused on the rehabilitation of existing public and social housing such as Uniacke Square in Halifax, Nova Scotia



Attention in the '90s has turned to facilitating a smoother code approval process for renovation and improving the industry's business skills through the National Renovator Training Program. Human Resources Development Canada funded a major training needs analysis under the Industrial Adjustment Services which provided the basis for efforts to improve professionalism in the industry.

### **Research, standards and technology transfer**

The *National Housing Act* gave CMHC a broad mandate to pursue research and educational activities in support of improved housing quality. The NRC's Division of Building Research, which became the Institute for Research in Construction in the mid-1980s, and Energy Mines and Resources Canada, which became part of Natural Resources Canada in 1993, were the two other federal agencies which undertook housing-related research. The scope of federal research, demonstration and information transfer activities is described in detail throughout this publication.

As previously mentioned, during this period, CMHC exerted considerable influence on construction quality through two vehicles: the

**Photo 8:**  
Many building code changes have resulted from NRC research using specialized testing facilities such as this column furnace



Materials Evaluation Service and the Residential Standards and related *Builders' Bulletins*. Although these only applied to NHA-financed housing, they effectively became the de facto standards for the housing industry. NRC took over CMHC's Materials Evaluation Service in 1988 and expanded it into the Canadian Construction Materials Centre.

Marginal-cost pricing can result in some equity problems when applied to facilities considered a necessity such as police stations, fire stations and sewage and water treatment plants. Some members of the community cannot afford to pay the full cost of building and maintaining these facilities. Thus, it might be appropriate to charge them less than the marginal cost.

Three responsive research programs at CMHC, all initiated in the 1980s, are also worthy of mention as being complementary to the directed research efforts: the Housing Technology Incentives Program, the External Research Program and the Scholarship Program. The Job Site Innovator Program, introduced in 1988, sought to encourage and recognize field innovation by builders and trades. NRC's Industrial Research Assistance Program (IRAP) was extended to the housing sector through a network of technical advisors.

From the mid-1980s onward, much of the research undertaken by CMHC and others was presented and discussed at National Housing Research Committee meetings. The Canadian Housing Information Centre (CHIC) also served as a focal point for transferring research to the industry and the public.

The Associate Committee on the National Building Code, which merged with the Associate Committee on the National Fire Code to become the Canadian Commission on Building and Fire Codes in 1993, continued to coordinate the ever-increasing requirements for house performance, while pursuing ongoing dialogue with the industry over cost implications. Revised model codes were produced on a five-year cycle throughout this period. CMHC applied its Residential Standards and *Builders' Bulletins*, which prescribed additional requirements, such as energy conservation measures, for NHA-financed housing until the mid-1980s. After this time, it relied on similar provisions enacted by local jurisdictions.

## **PART II**

# **INNOVATION IN PLANNING AND HOUSE DESIGN**

At first glance, the single most remarkable aspect of residential planning and design during this period was the apparent *lack of change*—the suburban developments of the mid-1990s were not all that different from those of the mid-1960s. However, this surface similarity belies a number of significant design changes which occurred. Also, the intervening years were characterized by many noble experiments in new directions. Some of these were failures but others succeeded in exerting a lasting influence.

Rather than presenting a detailed account of planning and design examples, this section is intended to complement Part I, *The Canadian Housing Scene*, by setting some additional context for housing technology innovation. Chapter 3, *Shaping the Residential Landscape*, examines urban and suburban development trends, while Chapter 4, *The Evolving Dwelling*, outlines significant changes to the design of housing units.

### **3. SHAPING THE RESIDENTIAL LANDSCAPE**

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Urban growth and population increases resulted in the steady and sometimes explosive growth of Canadian suburbs, creating an ongoing laboratory for experimentation and fine-tuning of planning principles. Some suburban communities became more self-contained with white-collar businesses, retail stores and high-tech industries relocating outside the traditional urban core. However, for the most part, Canada's cities remained relatively vibrant and safe in comparison with older American cities.

A number of significant factors—the baby boom, the decline of the nuclear family and interest in sustainable development, described in Part I—contributed to shaping the form of urban and suburban development over the 30-year period. The following pages outline the resulting impacts.

#### **Innovative Responses to Rising Land and Social Costs**

Canadians' continued preference for the "suburban dream" of the single-family detached home with a big yard became a reality for millions. They were aided by growing affluence, high inflation which reduced mortgage payment burdens over time, various government homeownership assistance programs and a willingness to commute. Suburban growth remained decidedly low rise. The alternative for singles, couples, the elderly and low-income families was apartment living.

The high demand for serviced land during boom periods, the high costs of servicing, the devolution of infrastructure costs from municipalities to developers, increasing development charges or lot levies, and bureaucratic delays in the development approval process all contributed to rising land costs, particularly in the largest metropolitan areas. The end results were higher urban densities and more expensive housing.

As suburban sprawl increased and apartments became taller, this polarization of Canadian housing was seen as unhealthy. On the one extreme, high-density developments were not regarded as creating suitable environments for families. They disturbed the character of existing neighbourhoods, blocked sun access and required more expensive construction techniques. On the other extreme, low-density suburbia was rapidly exceeding the bounds of affordability, requiring an extensive and inefficient transportation infrastructure, and being increasingly constrained by agricultural land use controls.

For housing to remain affordable, while providing socially desirable living environments, the answer was smaller lot sizes, alternative lot usage and experiments in medium-density housing.

#### **Innovative lot usage**

The standard 1960s lot width of 18 metres (60 feet) shrank in many municipalities to 12 metres (40 feet) and even 9 metres (30 feet). This had significant impacts on house design and appearance. Innovative approaches to planning allowed detached homes, or at least the illusion of detached homes, to be built on much smaller lots. Some examples included:

- zero lot line developments where setbacks on one or more building faces were eliminated;
- "link" homes which were officially semi-detached units, but built by developers as two separate houses joined only by a steel bar below grade;
- semi-detached or row housing joined only by garages or carports which were also referred to as "linked housing";
- zipper lots, in which units faced in alternate directions, with the front wider and the rear more narrow; and
- angled and offset lots which enhanced the street presence of narrow houses and provided more visual openness in side yards.

**Photo 9:**  
“Linked housing” refers to semi-detached or row housing joined only by garages or carports such as this example in Pointe-Gatineau, Quebec



The Mill Woods subdivision in Edmonton provided a living laboratory to test many of these concepts. Mill Woods was a large land bank of about 2,500 hectares (6,000 acres) acquired by the city and the province in 1970 to stabilize rapidly rising lot prices. Most of the area was developed by 1980, accommodating over 100,000 residents. Mill Woods was one of the first examples of a zero lot line development, allowing CMHC to field test its recently developed site planning criteria for small lots. An initial demonstration project, built in 1975-76, consisted of 49 detached units arranged in cul-de-sac clusters on lots of only 230 m<sup>2</sup> (2,500 sq. ft.), achieving a density of almost 35 units per hectare (14 per acre). The project demonstrated that detached houses on small lots were feasible, could achieve desirable densities and could result in significant savings over conventional developments [1].

### Experiments in medium-density housing

Medium-density housing meant recapturing the higher densities common in older urban areas, making more effective use of land and infrastructure, while maintaining low building height, ground-related access and adequate outdoor living spaces. Medium-density housing was seen as a solution to housing affordability and was vigorously promoted by CMHC and

the Canadian Housing Design Council, an independent agency which recognized innovation and excellence through an annual awards program. The Municipal Incentive Grant program

**Photo 10:**  
Mill Woods in Edmonton, Alberta tested concepts in innovative lot usage including “zero lot line” in which setbacks on one or more building faces were eliminated



also encouraged medium-density developments. Examples of innovative approaches, in addition to the detached forms noted above, included:

- “cluster housing,” with small numbers of attached units grouped around a cul-de-sac;
- courtyard housing, with L-shaped or rectilinear units joined in a checkerboard pattern at their corners;
- sawtooth row housing, where the stagger from one unit to the next was sufficient to provide greater individuality and privacy;
- narrow-front row houses, with widths of 4.8 metres (16 feet) or less;
- back to backs, where units were joined at the rear wall;
- multiplexes of up to eight units, each with ground level access;
- off-street row housing, with units often grouped around common parking and green spaces;
- stacked townhouses, with the upper units accessed directly from grade or via an interior corridor; and

- walk-up garden apartments, often with stair access eliminating the need for interior corridors and, occasionally, with the grade varying from front to back to allow as many units as possible to have ground access.

CMHC directly built or sponsored a number of significant demonstration projects in the 1970s to illustrate the advantages of medium-density housing.

LeBreton Flats in Ottawa was one of the most compelling. The 27 hectare (66 acre) former industrial site was acquired in 1962 by the National Capital Commission (NCC) and was cleared for a vast redevelopment program. A multi-agency planning structure, led by CMHC and the NCC, and including a citizens' council, coordinated the development, which was undertaken from 1974-1980. The objectives included a balanced community with a mix of income levels and types of tenure, integration with the existing neighbourhood, privacy and ground orientation, and public participation in the development process. The site was divided into 10 parcels and featured a variety of innovative medium-density approaches, including 4.2 metre (14 foot) narrow-front townhouses, stacked one- and two-storey townhouses, mid-rise apartments, interior "mews" courts for parking and access, and considerable attention to outdoor decks and privacy screening. The LeBreton project also provided a testing ground for numerous technical innovations, such as solar water heaters, sound barriers and district heating [2].

Another example was the Maryfield subdivision in Charlottetown, which was developed jointly in 1977-79 by CMHC, the province and the city. The development mixed detached, semi-detached, row housing and apartments. It achieved higher densities while preserving a natural meadow and creating play areas. Most units were arranged in clusters of two to four around cul-de-sacs. Some lots were angled and building setbacks were varied.

Photo 11:

LeBreton Flats in Ottawa, Ontario was one of several significant medium-density demonstration projects in the '70s to test technical innovations such as solar water heaters, sound barriers and district heating



#### Site planning for greater densities

CMHC's *Site Planning Handbook*, first published in 1966, established minimum requirements for lot sizes, setbacks, amenity areas, separation of land uses and the design for pedestrian and vehicular traffic. The aim was to ensure the long-term value of NHA-financed housing and to protect public interest. This evolved into *Site Planning Criteria* in 1977 and became increasingly important in the design of medium- and high-density projects [3].

Together with numerous advisory documents developed in the '70s and early '80s, such standards and guidelines provided the framework for innovative solutions to concerns over noise, privacy, adequate outdoor space, pedestrian safety and aesthetics. While no longer mandatory after 1980, except for social housing, these documents continued to represent the standard for good site design with respect to outdoor living areas, noise control and mobile home parks [4].

Some municipalities also developed elaborate planning guidelines, such as the Greater Vancouver Regional District [5] and the



City of Ottawa [6]. The Canadian Housing Design Council, with funding from CMHC, also promoted medium-density housing concepts and case studies through publications [7].

### **Lack of market acceptance of medium-density housing**

Despite the apparent societal advantages of medium-density developments as an alternative to the extremes of detached dwellings and highrise apartments, and despite the quality design of most demonstration projects, market acceptance was generally not achieved. The association of medium-density housing with social housing and cooperatives, perceived problems with resale value, privacy and noise, plus the higher social status conferred on the detached house meant that denser forms of housing were seen by most homebuyers as only a stepping stone on the way up. Turnover rates in medium-density market housing were high, and occupant satisfaction was much lower than for detached or high-rise units.

As a result, new housing developments by the end of this three-decade period tended to look much like those in the mid-1960s, dominated by single-family detached units. However, this did not mean that the experimentation with medium-density housing was a failure. On the contrary, the lessons learned were adapted and absorbed by various housing sectors. There is no doubt that the social housing of the '80s and '90s provided much more humane environments than the barrack-like public housing of the late '40s or the high-rise ghettos of the '60s. Niche market condominiums often incorporated a variety of medium-density design features. Virtually all forms of low and mid-rise, multi-unit projects began paying greater attention to outdoor living spaces and privacy. The stacked townhouse emerged as a successful alternative to walk-up apartments, having the same footprint but without corridors and common entries, and offering greater individuality, ground-related access and better use of outdoor space. Also, with declining buying power in the 1990s, the return to building starter homes saw greater use of more individualized attached and linked units.

### **New Approaches to Urban Renewal**

The combination of government improvement programs, economic development and Canadians' attraction to urban life led to a renaissance of most urban cores. The most impressive examples included Toronto's Cabbagetown, Vancouver's Gastown, Le Vieux Montréal and Winnipeg's warehouse district. Smaller cities and towns also made efforts to revitalize their main streets to compete more effectively with suburban shopping malls. Downtown housing represented an important element of urban revitalization in virtually all cases. This was based on the principle that having people downtown 24 hours a day instead of just from 8:00 a.m. to 5:00 p.m. would promote economic vitality and safe environments.

### **Shift to rehabilitation and infill**

The postwar approaches to slum clearance, with deteriorated neighbourhoods demolished for apartment buildings, ended in the late 1960s with the birth of community action groups and a growing realization of the value of rehabilitating existing housing. High-density, high-rise developments were recognized as contributing to, rather than solving, social problems and were complemented increasingly by mid-rise and low-rise infill projects.

The Strathcona Rehabilitation Project represented a watershed for urban renewal policy. A deteriorated residential area housing Vancouver's Chinese community, Strathcona had begun to be redeveloped by the city with medium- and high-density structures for public housing in the late '50s and '60s. With resident opposition organized under the Strathcona Property Owners and Tenants Association (SPOTA), CMHC imposed a moratorium on further development in 1969 and initiated a community rehabilitation project steered by the city, the province, CMHC and SPOTA. This represented an early example of including citizen participation in project planning in Canada. In 1972-74, public funds were invested in infrastructure upgrading, grants and loans to homeowners and landlords for housing repairs, and a linear park and adventure playground.

**Photo 12:**  
The Strathcona Rehabilitation Project in Vancouver, British Columbia represented a turning point in urban renewal policy by including citizen participation in the project planning process



In total, 30 per cent of all dwellings were rehabilitated and many more were improved without financial assistance. Infill units were also built. The desirability of Strathcona was greatly enhanced and resale prices rose. Most important, the project served as the model for the development of the RRAP program [8].

Context-sensitive, infill approaches were promoted through CMHC publications [9]. Many provincial housing agencies were also active in infill, most notably the Manitoba Housing and Renewal Corporation. They sponsored a design competition in 1982, which produced a number of very well-designed units suitable for integration in older Winnipeg neighbourhoods. CMHC also provided considerable guidance on upgrading older housing [10].

### **The impact of NIP, RRAP and CSCP**

The Neighbourhood Improvement Program (NIP), undertaken by CMHC from 1973-78, assisted municipalities in improving existing neighbourhoods through shared financing of social and recreational facilities and municipal utilities. Total contributions from the three levels of government were about \$500 million, and assisted 475 projects in over 300 municipalities.

The Residential Rehabilitation Assistance Program (RRAP), enacted as a companion program to NIP, was intended to improve the health, safety, appearance and energy efficiency of substandard and deteriorated dwellings. Various components were directed to homeowners, landlords and, later, people with disabilities. Continuing through the mid-1990s, RRAP contributed to over 400,000 dwellings being improved, while generating \$2.58 in private expenditures for every \$1 of public funding, and established the base for inspector and renovator training.

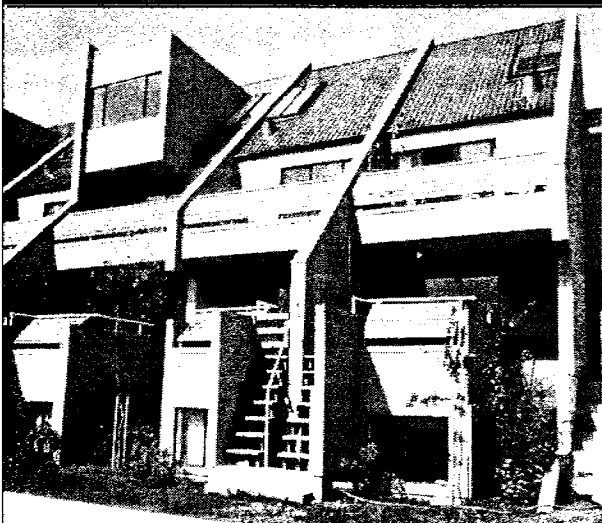
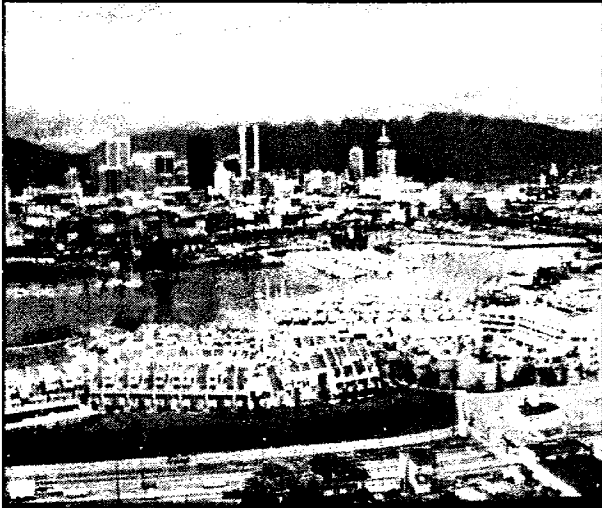
After the demise of NIP, the Community Services Contribution Program (CSCP) provided block funding to provinces from 1979 to 1984 to aid municipalities with neighbourhood and infrastructure improvements, assisting about 3,500 projects. The combined impact of these federal programs played a major role in securely establishing rehabilitation as the policy of choice for urban renewal [11].

### **Deindustrialization and inner-city redevelopment**

The gradual decline and removal of the old industrial base in most cities, accompanied by a shift to service, financial and high-tech employment, led to changes in the type of housing required. White collars replaced blue collars, spurring the conversion of older housing—often subdivided into apartments—back into upscale single-family dwellings and fuelling the construction of downtown luxury condos. The redevelopment of former industrial and transportation lands created opportunities for revitalizing urban cores with high-quality developments. The Toronto Harbourfront, encompassing luxury apartments, high-priced offices, hotels, shops and recreational facilities wedged between the Toronto skyline and Lake Ontario, provided one of Canada's most dramatic examples.

Several landmark projects paved the way for such inner-city developments which, at one time, were not regarded as feasible and were not possible in most American cities.

**Photo 13:**  
Vancouver's False Creek project in the '70s turned a derelict industrial area close to downtown into an extremely desirable environment for urban living. Eighteen hundred units were integrated in a variety of housing types and forms of tenure

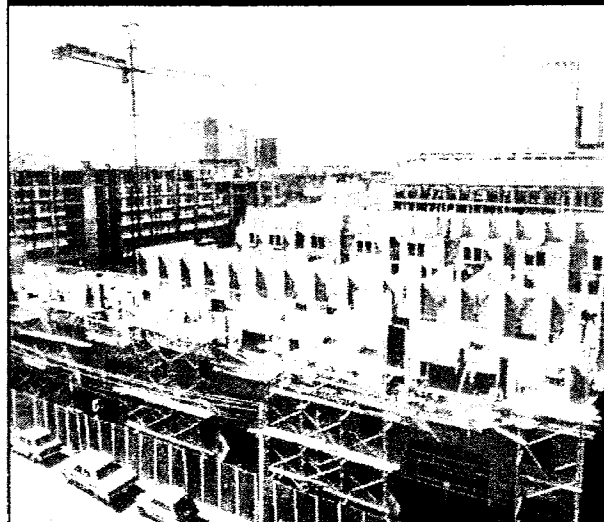


Perhaps the most significant was Vancouver's False Creek. In the 1960s, the False Creek Basin was a derelict industrial area within walking distance of downtown Vancouver. The city coordinated the acquisition of the lands and, in 1973, began redevelopment of 21 hectares (52 acres) on the south shore, using federal non-profit programs delivered by CMHC. One of the main objectives was to produce a socially mixed community. False Creek succeeded in achieving high densities with low-rise and

mid-rise buildings of two to 10 storeys. It integrated a variety of housing types and forms of tenure and created an extremely desirable environment for urban living. In total, 1,800 units were built [12].

Similarly, the St. Lawrence project, located adjacent to Toronto's St. Lawrence Market, mixed market and social housing in a dense environment without resorting to high-rise towers. Construction was initiated in 1977, resulting in 3,500 units in three- to eight-storey structures and integrating considerable commercial space [12].

**Photo 14:**  
The St. Lawrence project in downtown Toronto, Ontario mixed market and social housing along with commercial space without building over eight storeys in height



Another example initiated in the late 1970s in support of the revitalization of Montréal's Le Vieux Port area was La Cour St. Pierre, a collection of six warehouse buildings which were converted to residential and mixed uses [13].

## International and Environmental Influences in Canadian Planning

### International planning trends

Post-war suburban growth followed the "garden city" approach first developed in England at

the turn of the century and implemented extensively in the United States in the 1920s. The development of Toronto's Don Mills area in the 1950s exemplified this approach in Canada. Many of the subsequent American design concepts for increasing density in suburbia, such as cluster housing and other forms of planned urban developments (PUDs), were also picked up by Canadian developers. Condominium ownership, developed in the United States to take advantage of the tax deductibility of mortgage interest, was also imported into Canada, causing a boom of condo construction in the 1980s in major cities. The post-war rebuilding of European cities—traditionally much denser than their North American counterparts—provided examples of alternative approaches to medium- and high-density housing forms.

Near the end of this period, the growing dissatisfaction in the United States with development patterns and their negative effect on the quality of life contributed to the birth of the neo-traditional planning movement. Neo-traditionalists rejected modernism and the cul-de-sac street layouts of “garden city” approaches and advocated a return to late 19th century models. These placed an emphasis on compact developments, a rectilinear street grid, higher densities, a mix of housing types and places of employment, street orientation with reduced setbacks and rear parking/servicing, main streets and town squares. By the mid-1990s, several neo-traditional communities were being planned or implemented in Vancouver, Toronto, Calgary and Edmonton.

### **More sustainable planning**

Global concern over the environment and sustainability led to the development of alternate land use planning standards to reduce land wastage and increase densities. An example was the Regional Municipality of Ottawa-Carleton, which advocated narrower right-of-ways, reduced setbacks and smaller lot sizes. “Ecosystem” approaches to planning began to be incorporated into major studies, such as the Royal Commission on the Future of the Toronto Waterfront. CMHC undertook pioneer work on sustainable forms of suburban development involving mixed-density pockets, “metropolitan purlieus” and other forms of “intensification” [14].

However, despite significant numbers of studies, proposals and conferences, such environmental concern had produced little change in actual planning practice by the mid-1990s. The Canadian public and municipal politicians, while supportive of the concept of sustainable development, were resistant to any changes which were perceived to affect local property values or neighbourhood character. In some ways, the debate was more academic than real. With Canada's population levelling off and the number of new housing starts declining, the existing development patterns established during the 50 years after World War II, encompassing more than three quarters of the total housing stock, appeared destined to remain the dominant characteristic of Canadian cities for decades to come.

## 4. THE EVOLVING DWELLING

Demographic, lifestyle and planning changes influenced housing design, size, appearance and amenities. These next few pages summarize the underlying factors and the results.

### House Size, Form and Amenities

#### Designs for affordability

Affordability was a key issue throughout much of this 30-year period, primarily because of the large numbers of baby boomers entering the housing market. House size only increased marginally through the '50s, '60s and '70s, averaging 100 to 110 m<sup>2</sup> (1,100 to 1,200 sq. ft.). CMHC sought to encourage well-designed modest homes, continuing its tradition of publishing plan books with the release of *Small House Designs* in the mid-1960s. This publication reflected the increasing mix of house types in suburbia, including bungalows, raised bungalows, split levels and two-storey designs. The 1977 sequel, *Modest House Designs*, continued the tradition, emphasizing bi-levels and semi-detached units.

In the '70s, average unit sizes actually decreased, due to the large number of small AHOP-financed homes and MURB units built. Medium-density projects featured compact layouts, with minimal hallways, small children's bedrooms, efficient kitchens and well-planned closet and storage areas. To aid in promoting efficient designs, which made the most of limited floor space, CMHC provided publications detailing room and furniture layouts [1].

#### Monster homes and luxuries

By the 1980s, the cumulative impact of Canadians' growing affluence through the '60s and '70s led to an increase in house size, with builders catering to the "move-up" market and double-income families. The baby boom generation of homebuyers, while having fewer children than their parents, had far more possessions. Average house sizes increased to about 185 m<sup>2</sup> (2,000 sq. ft.). In addition, these

**Photo 15:**

**The affluence of the '80s brought an increase in average house size and the construction of so-called "monster homes"**



newer homes were two or two and a half storeys and had higher roof profiles and multi-car garages, all of which combined to make newer housing look much larger than postwar units. "Monster homes," built particularly in the overheated Toronto and Vancouver markets in the late '80s, were usually 280 to 470 m<sup>2</sup> (3,000 to 5,000 sq. ft.). Because these often appeared out of scale on small suburban lots and especially as infill in older neighbourhoods, they received much criticism from the public.

Canadians' affluence also led them away from the functional, casual and often bare-bones modernism of the postwar years to a greater emphasis on luxury, comfort, formality and decoration. New houses had more amenities: more and larger bathrooms, whirlpool baths, central air conditioning, more kitchen cupboards and appliances, walk-in closets, central vacuums and one or more fireplaces. Master bedrooms became enormous. Many homes featured spacious entries, accompanied by grand "Scarlett O'Hara" staircases. Higher-quality finishing materials such as hardwood, ceramic tile, paving stones, brick, and textured paints and wallpapers became selling features. Increasingly, houses had to

accommodate large screen entertainment centres, elaborate sound systems, various office equipment and home automation systems.

Similar to low-rise housing, apartments—at least those built for condominium ownership—became larger and more luxurious. In addition to improvements in the individual units, such as double master bedrooms, additional baths, dens/guest rooms and sunrooms, projects offered a greater number of common amenities, such as elaborate recreation facilities and party rooms.

### **Impact of smaller lot sizes**

The narrower frontages caused by escalating urban land prices in the '70s also posed a serious challenge to dwelling design. Combined with the trend to larger units and the continuing preference for detached homes, the most visible impact of smaller lots was a gradual transition (except in rural areas where lots remained large) from bungalows, bi-levels and split-level units oriented laterally across the site to two-storey homes oriented longitudinally. This meant a return to monotony, with garages dominating the streetscape and difficulties in squeezing a window and an entry into the remaining front face of the house. To break out of these severe restrictions, some builders had reverted to wider but very shallow lots by the 1990s.

**Photo 16:**  
Narrower lot sizes, as a response to escalating urban land prices, resulted in the streetscape in some subdivisions being dominated by garages



In multi-unit housing, CMHC promoted the concept of the narrow front townhouse. In the LeBreton Flats demonstration, the combination of front-to-back split-level design, interior skylights over the stairwell, decks over the carport and open planning created very bright and pleasant interiors in only 3.6 m (12 ft.) of frontage. McGill University's Grow Home similarly represented a narrow front approach to starter homes which could be built as detached units or as row housing [2].

**Photo 17:**  
McGill University's "Grow Home" addressed the need for starter homes on narrow lots. They can be built as row housing or as detached units



## **Designing for Changing Lifestyles**

### **The use of space**

The growing amount of time devoted to careers and the gender revolution meant less time at home and a need for more functional kitchens, more space for convenience appliances and more parking space for multiple cars. The open plan of the 1960s home gradually reverted to a hybrid of an open plan and a traditional layout, featuring a seldom-used living room and dining room at the front and interior of the main floor and a large open kitchen/eating/family area at the rear. Kitchens, which had become increasingly efficient but smaller in the immediate post-war era, became larger and regained prominence as the central focus of

the house, a place to entertain guests informally while meals were prepared or served.

### **An evolving role for the basement**

To accommodate additional space economically for a diversity of family functions, the basement took on greater importance in the '60s and '70s. Basements were built with higher ceilings and greater levels of moisture and thermal control, and were soon packed with recreation rooms, workshops, darkrooms, teenage bedrooms and spaces for other activities. Innovative designs overcame the lack of natural light. Bi-level or high ranch units, with split entries and shallower foundations facilitated large basement windows suitable for extra bedrooms. These designs were

**Photo 18:**  
Bi-level houses with split entries allowed larger basement windows and more opportunity for habitable basement spaces



ideal for modest family housing and became especially popular in the Prairies. Similarly, split-level designs elevated half of the basement to a better lit, more amenable space. As the emphasis shifted to larger, more luxurious homes in the '80s, functions that had been traditionally located in the basement such as the family room, laundry room and the fourth bedroom or den, were relocated to upper levels. This left basements empty again, although they were still considered a must in all areas except British Columbia.

### **More functions under one roof**

By the end of this period, homes were being used more intensively. The rapid advances in computer and communications technology which had taken place by the late '80s and early '90s, combined with more informal structures in the workplace, led to the birth of the home office for home-based employment or telecommuting. Main floor offices were offered by several builders as a "hot button" option. Accessory apartments, often illegal but openly tolerated, resurfaced as a major source of affordable accommodation. This was particularly true after official recognition in Ontario in the '90s, and because they could also serve as in-law suites for elderly relatives.

### **The importance of the automobile**

The continued dependence on commuting meant more cars per household and, therefore, more space for parking. The carports and open driveways of the '50s and '60s were replaced by multi-car garages which often dominated suburban streetscapes. In multi-unit housing, the lack of visitor and second car parking posed a perennial problem, and there was general dissatisfaction with parking garages due to concerns over security and vandalism.

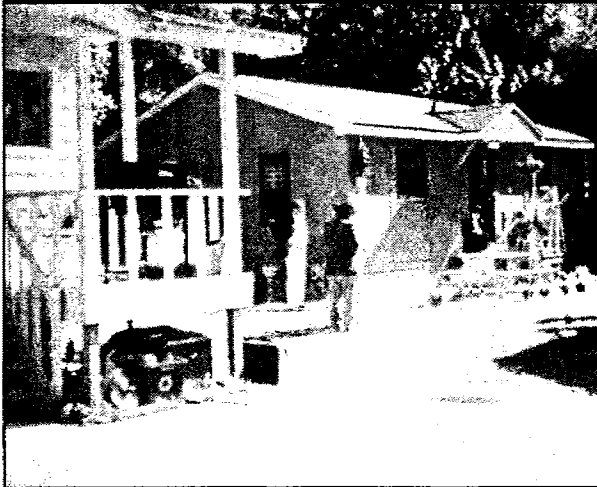
### **Designs for the elderly and disabled**

Recognition of the need to provide disabled persons with greater access to non-institutionalized housing gave birth to barrier-free design in the 1970s. A greater number of apartments and social housing units incorporated wider doors, wheelchair turnaround space and more accessible kitchens and bathrooms. CMHC's *Housing the Handicapped* (later revised as *Housing the Disabled*) provided design guidance [3]. HUDAC built a demonstration house in 1975 called Housing for Independent Wheelchair Living.

The ageing population and the recognition of the importance of "ageing in place" provided even greater impetus for work on accessible designs. CMHC pursued considerable research throughout this period on housing options for seniors. *Housing for the Elderly*, first released in 1970, was followed by numerous guides,

including advice on home adaptations [4]. CMHC demonstration projects exerted a significant influence. In the '80s, the garden suite demonstrations led to the acceptance of this form of seniors' accommodation in many municipalities [5]. The Charlie House joint

**Photo 19:**  
Demonstrations of Garden Suites, such as this A-C-T project in Fredericton, New Brunswick led to greater acceptance of this form of seniors' accommodation



venture with CHBA in 1989 demonstrated the concept of adaptable housing which could be divided into two separate units [6]. In the '90s, the Open House promoted accessibility and independent living for those with a variety of disabilities.

### **Computer-aided design**

By the 1990s, the availability of powerful, user-friendly computer-assisted design (CAD) software began to facilitate easier customization of homes to suit individual lifestyles and tastes. Even small builders began offering computer "walk-throughs" of proposed designs for prospective buyers.

## **Design Trends vs. Tradition**

### **International influences**

The influence of international architectural trends on Canadian housing has always been somewhat muted and indirect. The modern or international movement, which was developed

early in the 20th century, dominated commercial and institutional construction after World War II. The residential expression of modernism, epitomized by the designs of American architect Frank Lloyd Wright, influenced the ranch bungalows which dominated Canadian suburbs in the '50s and '60s, with their low profiles, clean lines, open plans and horizontal sliding windows. These evolved into the contemporary designs of the '70s, characterized by clerestory roof lines, simple geometric shapes, narrow vertical windows, diagonal cedar siding, patio doors and decks.

### **Traditional styles**

Throughout this period, despite significant numbers of custom-designed projects at the leading edge of modern—or later post-modern and deconstructivist—design, mainstream housing preferences remained decidedly less architectural and more traditional. The appeal of traditional house styles such as Colonial, Victorian, Georgian and Cape Cod remained strong, despite decades of architects' criticisms of such "applied decoration". By the 1980s, the combination of large boxy houses on small lots and the return to more conservative values led to a final rejection by homebuyers and builders of the perceived sterility of modern design. Traditional styles re-emerged. Elaborate brickwork, gingerbread, porches, paned windows, dormer roofs and cupolas—in varying degrees of historical accuracy—characterized the street facades of many new houses in the '90s. Critics regarded this as a Hollywood stage-set approach to design, since in all but the most upscale developments, the side and rear facades were inevitably vinyl siding.

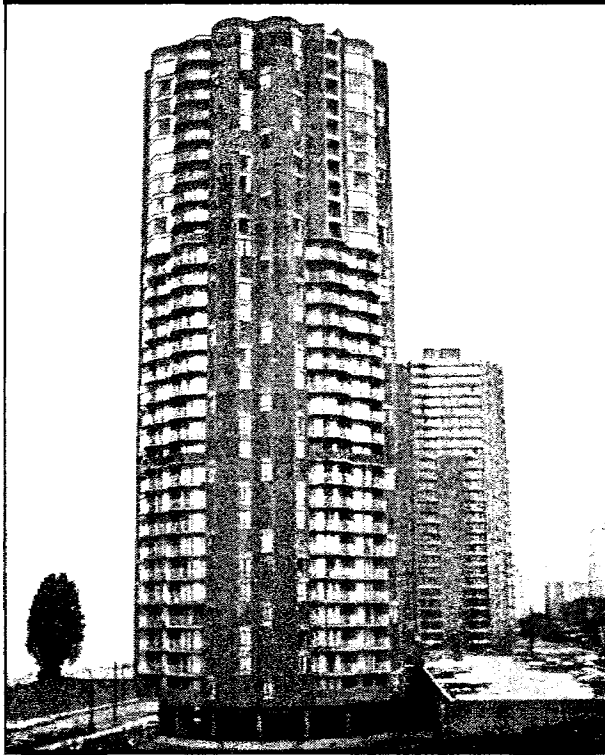
### **Apartment facades**

Similarly, the exterior design for the initial wave of high-rise apartments in the '60s was often exposed concrete, in keeping with "brutalist" architecture. This was gradually superseded by the use of brick, precast concrete and exterior insulation and finish systems (EIFS). While rectangular slabs remained common, the growth of the condominium market in the '70s and '80s included more variety in form, including



“point blocks” (apartment towers with few units per floor to provide multiple exposures for each unit), geometric shapes and terraced designs intended to soften the massiveness of such buildings. Point block towers dominated in Vancouver due to the importance of views. Post-modern design elements, such as arches, Palladian windows and decorative columns, were often incorporated in the 1980s, particularly at the entrance and penthouse.

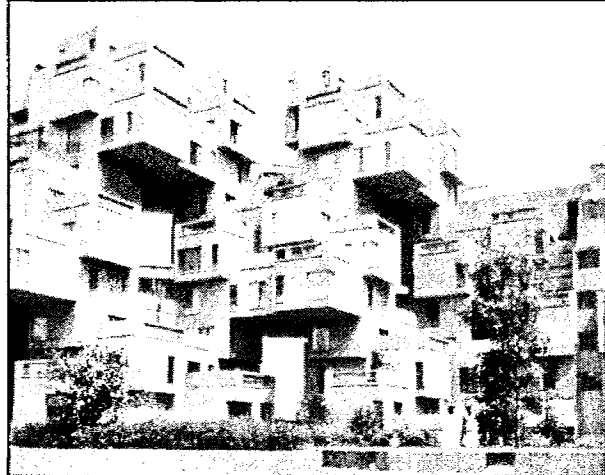
**Photo 20:**  
This “point block” in Vancouver, British Columbia exemplifies the shift away from rectangular floor plates in condominium construction to maximize views



### National design influences

Habitat, the modular “gardens-in-the-sky” experimental housing complex designed by Moshe Safdie for Expo '67 in Montréal, was perhaps Canada's most significant project in international design circles, but was not repeated. Architect Arthur Erickson's work has been more influential and has helped shape the distinctive West Coast style, which seems so appropriate in

**Photo 21:**  
Moshe Safdie's experiment in modular housing—Habitat—was a showpiece at Expo '67 in Montréal, Quebec



British Columbia's rugged landscape, and has dominated residential design competitions. Other parts of the country have also maintained their regional design flavour, often drawing elements from their heritage, such as narrow board siding and steep roofs in Atlantic Canada, Victorian gables and gingerbread in Ontario, and mansard and “québécois” roofs in Quebec.

The Canadian Housing Design Council (CHDC) played an important role in recognizing and disseminating innovative design solutions through its awards program and publications, until its demise in the early 1980s. In the multi-family sector, where architects were involved, CHDC's role was particularly valuable in promoting new concepts to a national audience. The Royal Architectural Institute of Canada (RAIC) and the provincial architectural associations have filled the gap with similar awards programs. Annual design awards sponsored by CHBA's local homebuilders' associations also encouraged attractive and functional designs.

In the late '80s and '90s, CMHC's Housing Awards Program filled a similar role, with biennial awards targeted to specific user groups, such as the elderly, those with a disability, Aboriginal peoples and young families.

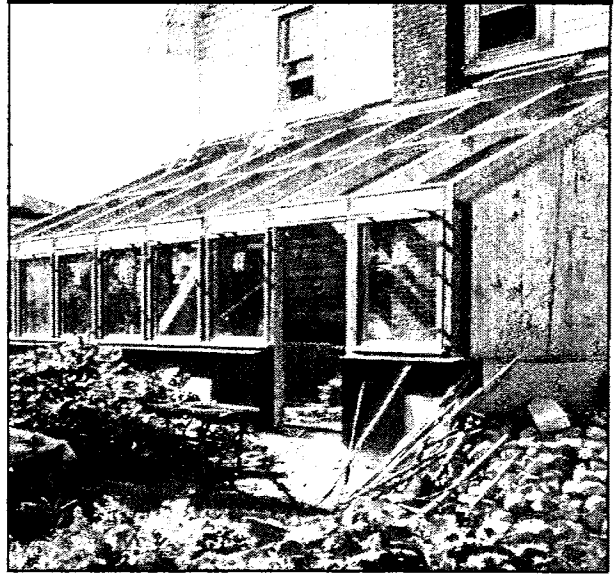
### Impact of energy efficiency on design

The appearance of some of the early examples of energy-efficient demonstration housing built in response to the energy crisis may have appealed to energy buffs but not to the public, who were not enamoured with windowless north facades, massive solar collectors or underground dwellings. In recognition of the importance of market appeal, both CMHC, through its publications, such as *Passive Solar House Designs for Canada* [7] and EMR and CHBA, through the R-2000 program promoted the incorporation of energy-efficient design into conventional-looking housing. R-2000 is discussed in greater detail in Part IV of this report. The use of sunspaces or greater amounts of southern glazing was generally kept subtle and well integrated. In mainstream housing, energy consciousness also had design impacts. Although not just for energy reasons, the large expanses of glass, cathedral ceilings and sprawling floor plans of the '60s gave way to smaller windows and more compact forms.

### Transforming Older Housing

The renovation boom had a transforming effect on the existing housing stock, with more than half of all expenditures going toward additions and major renovations. The most popular improvements were functional, with kitchens and bathrooms being modernized. Smaller homes were expanded, often to the rear with family rooms and larger master bedrooms, or upward with additional bedrooms over a bungalow or garage. Outdoor living areas, such as porches, sunspaces and decks were added.

**Photo 22:**  
Sunspaces became popular additions to older homes



Building components, particularly windows, roofing, cladding, flooring and interior finishes were upgraded or replaced on an ongoing basis. In some cases, this restored traditional appearances and, in other cases, changed appearances radically. By the '90s, it was very rare for prospective homebuyers to find an older house which had not been at least partially renovated or remodelled.

## **PART III**

### **INNOVATION IN THE PRODUCTION PROCESS**

The post-war years involved a massive expansion in Canada's housing production capability, accompanied by a revolution in construction methods, which greatly reduced on-site labour. Many of these changes were documented in *Two Decades of Innovation in Housing Technology: 1946-1965*. Part III of this report continues this story through the 1960s and early '70s, by which time the most significant production changes had taken root. Additional developments in the later years are also noted briefly, although the period from the '70s to the '90s was characterized more by improvements in housing performance than in housing production, as is chronicled in detail in Part IV. Materials in Part III draw heavily on Working Paper Two of *The Housing Industry: Perspective and Prospective* [1].

## 5. THE AGE OF THE BIG BUILDERS

By the mid-1960s, leading builders could well imagine themselves as masterful riders of a fast-evolving production machine: a machine comprising fewer, larger producers, rooted increasingly in the factory or factory-like processes, turning out houses with slicker new materials, components and much less labour.

Apartment builders could also picture their industry as similarly poised in the mid-1960s: well on the way to a faster, more factory-based production machine—and anticipating 50-storey tower blocks that previous generations could have scarcely imagined.

**Table 1:  
Outline of Changes in Mainstream Housing Production**

Component	Mid-1940s	Mid-1960s
Excavation	Horse-drawn scrapers replaced by bulldozers. shaping and trenching disappeared.	Bulldozer yielded to backhoe. Hand shovel
Basements	Concrete blocks gave way to site-mixed poured concrete, with site-built board formwork. First transit-mixed and oiled-plywood forms used. Still some dirt floors.	Transit-mixed concrete and prefabricated plywood formwork. Blocks still served in rural areas and board formwork still used in Atlantic Canada. Concrete slabs.
Wall Framing	Typical builders used platform frame, but still some balloon frame used. West already used tilt-up and "stationary assembly line" processes.	Pre-cut studs, tilt-up, "stationary assembly line" with sequencing of piecework subs. Floors provided the "assembly table" areas for the walls, partitions and roofs.
Roofs	Still laid out and erected by skilled carpenters, with site-cut and fitted rafters.	Engineered, manufactured roof trusses took over typical house production.
Plumbing and bathrooms	Cast iron waste vent. Some galvanized steel. Site-fitted and installed. Bathtub and tile all installed separately.	Little change, but plastic drain waste vent piping speeded up on-site process.
Electricity	30-50 amps typical.	60-100 amps typical.
Heating	Gravity furnaces common.	Forced-air furnaces and electric baseboards. Ductwork sub-assemblies. Prefabricated chimneys became common.
Interiors	Wet-finished plaster walls and ceilings, cured, then brush painted. Hardwood and linoleum flooring.	Interiors were drywalled and roller-painted. Hardwood floors still typical, but carpeting gaining in popularity.
Windows	Still fabricated on site. Single-glazed, vertically hung, often with storms.	Manufactured windows, usually sealed double-glazed, horizontal sliders. Aluminum frames common.
Cabinetry, stairs, millwork	Still fabricated on site. Countertops were often lino or painted wood.	Manufactured cabinetry. Melamine for countertops.
Wall and roof sheathing	Used boarding (often stripped from the basement forms).	Plywood sheets widely used. Fibreboard used with brick or stucco.
Siding	Often clapboard applied, trimmed and painted on site using scaffolding. Brick and stucco dominant in some areas.	Pre-coated aluminum and hardboard competed strongly with wood. Brick and stucco often on first storey.
Insulation	Walls uninsulated or 5 cm (2 in.) of mineral wool or shavings. Vermiculite in attic.	Still minimal: 10 cm (4 in.) fibreglass batts in walls, 15 cm (6 in.) in ceilings. Cellulose introduced. Some insulating of basements.
Air/vapour barriers	Little awareness.	Kraft paper on batts. Some use of 2 mil polyethylene. Drywall and sheathings increased airtightness inadvertently.
Ventilation	Natural.	Some use of exhaust fans.
Scheduling, job control, costing	Rudimentary.	Generally effective costing and control among the larger builders.

**Table 1 (Continued):  
Outline of Changes in Mainstream Housing Production**

Component	Mid-1980s	Mid-1990s
Excavation	No change.	Backhoe yielded largely to the excavator.
Basements	Generally no change, but steel forms increasingly used. Preserved wood foundations began to gain acceptance.	Little change, but more attention to drainage layer/membrane components. Granular fill and poly under slabs. Sub-slab venting and sealing for radon.
Wall Framing	Adaptations for thicker insulation and less bridging. Power nailers. Wood composite joists introduced. Some reversion to custom building because of large complex houses.	2 x 6 wall framing more common than 2 x 4. Engineered wood composites are widely used. Steel framing is taken seriously to the walls, partitions and roofs.
Roofs	High heel trusses to accommodate ventilation baffles.	Little change.
Plumbing and bathrooms	Easier, faster fittings and all-plastic plumbing. Plastic tub-shower units gain foothold.	Water-conserving fixtures. Plastic tub-shower and whirlpool baths are new standards.
Electricity	100 amps typical, 200 amps for electrically heated homes.	Energy-efficient lighting and appliances. Home automation and efficient fans and motors introduced.
Heating	Mid- and high-efficiency furnaces introduced. Oil largely supplanted by natural gas, where available. Airtight wood stoves and fireplace inserts. Chimneys and flues typically prefabricated.	Mid- and high-efficiency gas furnaces taking over. Requirements for spillage resistance. Central air conditioning increasingly common. Gas fireplaces popular. Combined heat/ DHW introduced.
Interiors	Carpeting and sheet vinyl placed directly over sheathing. Pre-finished plastic trim enhances speed.	Low-emission finishes introduced. Plastic or wood-plastic trim is new standard.
Windows	Improved thermal performance introduced: low-e coatings, gas fills, thermal breaks, less air leakage.	"Super windows" taking over.
Cabinetry, stairs, millwork	Little change. Pre-hung doors and prefabricated stairs often used.	Little change. Complete kitchen assemblies are standard.
Wall and roof sheathing	Waferboard sheets dominate.	Waferboard still dominates but insulating/ air barrier sheathings common.
Siding	Vinyl siding complete with other claddings. On-site painting essentially disappears.	Vinyl widespread. Fibre-cement composites begin to compete.
Insulation	Higher levels becoming common: R20 walls, R30 ceilings. Partially insulated basements typical.	Higher levels typical. Greater variety of high-performance insulations. Full-height basement insulation common.
Air/vapour barriers	Polyethylene increasingly sealed and continuous as air/vapour barrier; 2 mil replaced by 6 mil. Introduction of house wraps.	Variety of approaches to airtightness. Introduction of vapour barrier paints. House wraps common.
Ventilation	Heat recovery ventilators and central exhaust systems gaining in popularity.	Mandatory ventilation requirements. HRVs increasingly common.
Scheduling, job control, costing	Little change. Some use of computer-based costing and job control. Introduction of CAD.	Little change. CAD often used for both designing and selling.
Source: Scanada [1], updated 1996.		

Little of this came to be. The leading housebuilders maintained their efficiencies and economies of scale, but did not advance much further. Much of the story relates not only to the assimilation of more "factory content", in which the whole industry succeeded (see Table 1), but to

the struggle of the innovators toward the elusive goal of wholly factory-based or manufactured housing. The struggle is indicative of the uneven technological evolution of the whole industry across the vast reaches of Canada, in the face of both real and perceived constraints.

## Big Builders Adopt the Factory Concept

The housing scene of the 1960s was marked by the coming of age of large-scale building operations across much of Canada, most of them featuring their own house factories. These duplicated the central shop facilities of the long-established open-market house manufacturers, but were used to manufacture house packages for the builders' own projects on developed land. By the mid-1960s, "project manufacturers" were each building from 200 to 800 houses a year, totalling perhaps over 5,000 houses annually. These large builders relied heavily on their new plants, beginning with warehouse operations that allowed rail-car volume purchasing that cut out the building supply dealer. These operations were largely rooted in the wartime and post-war responses to the "big buyers": the Defence department and Central Mortgage and Housing Corporation.

Engineered Buildings (later Engineered Homes) in Calgary and Quality Construction (later Qualico) in Winnipeg and Calgary dominated the larger builder business throughout the West. Engineered Homes operated its factories to supply its own projects as well as open markets through widespread dealerships. The company pioneered cabinetry manufacturing methods and such advances as controlled fresh air supply through the return air plenum.

Campeau Corporation and Minto Construction dominated the booming Ottawa market with similar closed-market, project-manufacturer operations. Toronto had its Bramalea operations in exterior shell production for a time and Rockett Lumber in full production.

The various plants produced windows, stairs, cabinetry and trusses for the open market, as well as the exterior shell in open-panel form. Campeau sold its water tap-powered dishwashers and its modular partition system. While not successful in flexible-layout houses as intended, it succeeded in office buildings. The company's research and

development included large-panel steel joist floor assemblies, which reverted to wood to regain the necessary dimensional precision.

In addition to the move of large project builders to their own shops, other changes were occurring through the '60s. The small and medium builders, facing a buyer's market and increased competition, turned more to the open-market house manufacturer for house packages and assistance with financing and land development. These sporadic developments had already given the established prefabricators a foothold in the larger towns and cities. Smaller open market prefabricators served rural and small town markets.

**Photo 23:**  
Rothwell-Perrin, an innovative leader in closed panel housing production, operated their plant in Portland, Ontario from the '60s to the late '70s  
*Photo courtesy R.E. Platts*



Further, all builders were now using prefabricated components in their houses to a remarkable degree to replace high-cost, high-labour content items. Window assemblies were already factory-made components. But it was only in the 1960s that builders changed over to prefabricated cabinetry. The use of pre-hung doors and window sub-assemblies spread slowly, while engineered roof trusses swept the field once the NRC evolved

rational testing and design criteria. Masonry chimneys began to yield to factory-built flues.

On the other hand, the high-labour service items of the house—plumbing, wiring and, to a lesser extent, heating—continued to escape rational prefabrication. Plumbing was still generally required by local codes and trades to be cut, fitted, installed and inspected on site. Provincial electrical authorities sometimes agreed to factory inspection of wiring jobs, thus allowing pre-wired wall sections.

### **Bolder Prefabricators Face an Uphill Battle**

In all of this, builders stayed close to conventional wood frame construction, whether produced in plants or on site. Efforts at somewhat more radical innovation ran into arbitrary constraints or indeed roadblocks, and the anticipated advantages no longer seemed worth the fight.

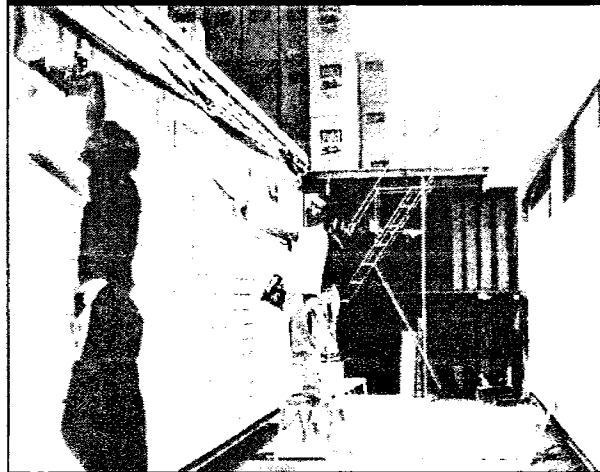
For example, Aero Marine Industries in Oakville, Ontario, developed an integral fibreglass reinforced plastic (FRP) unit bathroom in the '60s and produced a number of them for Bishop Homes. Concurrently, Polyfiber in Renfrew, Ontario, began developing an integral FRP bathroom-utility core back-to-back unit. These activities stopped when investigations suggested that local codes and trades would have to be overcome painfully, one by one, and some not at all.

In another example, A.V. Roe Ltd. (Avro), when considering furthering its Can Car division's venture into modular housing, voiced fears about obstacles that were never encountered in their development of aircraft, railway cars or transport trailers. Municipal code wrangles and piecemeal approval processes would defeat any hopes of volume marketing even of the company's conventional wood framed modular units and any further efforts at real innovation would be similarly forestalled or defaulted. Despite considerable success in providing fine houses to the Bomarc missile base in La Macaza, Quebec,

Avro withdrew from its home manufacturing venture.

The rationalization of codes and jurisdictions eventually cleared a somewhat wider path for marketing modular housing, at least in conventional wood frame form. Alcan set up a major modular venture in Ontario in 1966, but still found it difficult and costly to pick its way through local approvals one by one. The venture changed hands and, for a variety of reasons, it folded.

**Photo 24:**  
Big industry tried its hand in housing production, generally in the modular housing market. The Alcan plant set up in the mid '60s served southern Ontario  
*Photo courtesy Scanada Consultants*

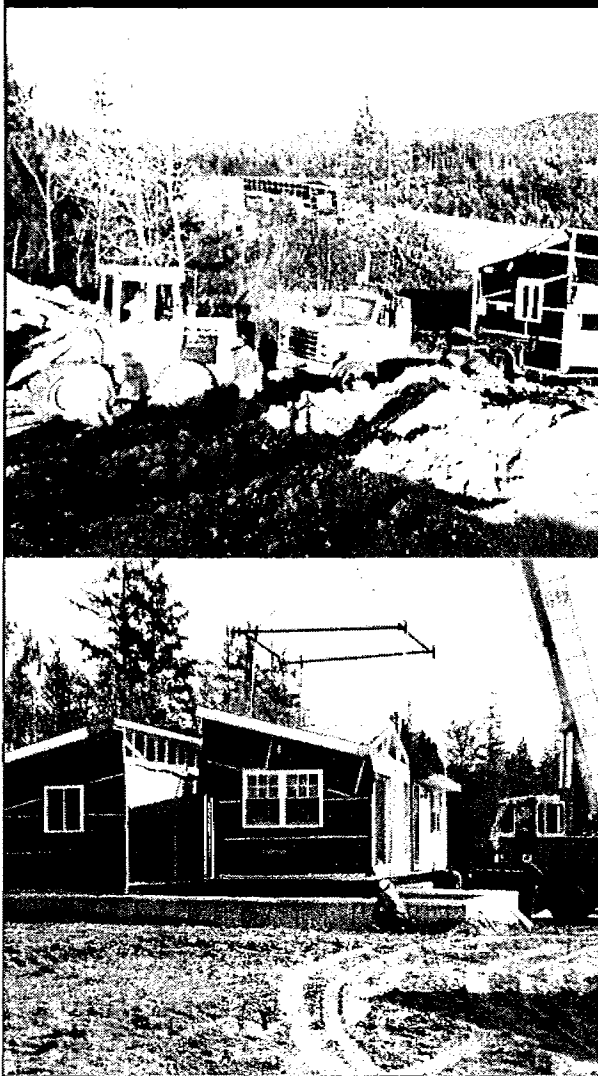


Nevertheless, there was, for a time, a regional boom in modular housing, particularly in Quebec, the Atlantic provinces and in a few areas of the West. In the peak years of the 1960s and '70s, manufactured housing captured as high as 21 per cent of all single-family house production, tripling the six or seven per cent common in the mid-1950s. While there still remained differences in regional acceptance, by the 1980s and early '90s, this type of housing had returned to again holding six or seven per cent of the single-family market.

**Photo 25:**

Developing isolated townsites: In the '80s particularly, modular housing systems were used to build mining towns such as this example in New Brunswick

*Photos courtesy Scanada Consultants*



If the big builders had been fostered, in part, by institutionalized opportunity, such as the defence housing programs and CMHC's financing of veteran's housing, they were, in turn, hurt by further institutional changes.

### **Winter building vs. Unemployment Insurance**

The public incentives of the mid-1960s to build through the winter were particularly favourable to factory-based builders, with their investment

in plant and their interest in retaining a core of competent staff and crew throughout the year. Then came the Unemployment Insurance (UI) program, extending its "seasonal" protection to cover long periods of slack—including winter. Small builders could now "park" their own key staff, in effect, on the UI program for the winter. Big builders were not as flexible.

### **Assisted Ownership Assistance Program**

The introduction of AHOP in 1973 spurred considerable activity among small builders, but worked to the detriment of the mobile home sector of the manufactured housing industry, which had been thriving at that time. AHOP grants and loans were only given to site-built homes, drastically cutting the demand for mobile homes.

### **The cost of money**

When interest rates soared at the close of the 1970s, the operations of all homebuilders were decimated, but those leaders with the most plant and the largest land banks fared the worst. The market revival in the mid-1980s was generally characterized by the demand for larger, more costly homes, generally built in smaller projects, which did not invite any greater degree of prefabrication than that used by all builders with no plant of their own. Small builders returned in great numbers, buying piecemeal from building supply dealers, mirroring the late 1940s. However, house factories generally remained closed into the '90s, except in areas where a demand continued for modest modular houses at reasonable costs.

The on-site homebuilders, with their factory-like process, power tools and full array of sheet materials and prefinished components continued as Canada's mainstay of housing production. The large factory-based builders, however, had left their mark by leading the way to a remarkably productive building process.

One of the noteworthy survivors from the era of factory-based builders was Minto Construction in Ottawa, which remained one of the largest builders in Canada. Minto maintained its plant



facilities, prefabricating open panel systems. More important, Minto succeeded in organizing its on-site production with factory-like precision, breaking down the construction process into a series of one-day and half-day tasks that could be undertaken by specialized crews or subcontractors, thereby shortening construction schedules.

## **Manufactured Housing: Surviving but Not Thriving**

The demise of the factory-based builders brought about a certain degree of polarization between site builders and manufactured housing. The public and municipal regulators often equated manufactured housing with trailer parks and showed a distinct preference for site-built homes.

Manufacturers diversified into a variety of “panellized” and modular systems, finding niche markets in mining communities, Arctic settlements, cottage country, rural areas, the United States and overseas. The industry also expanded into a number of new specialty areas. CMHC assisted the development of free-standing, self-contained garden suites (granny flats), which became a seniors’ housing alternative

after overcoming regulatory resistance at the local level. NRCan’s R-2000 Program collaborated with CHBA and other industry partners to develop “R-2000-ready” units, adapting the quality control possible in factory construction to meet energy efficiency requirements. McGill University’s successful Grow Home concept was industrialized using a system of wall panels. Labour shortages in the Toronto area in the late ’80s created an opportunity for some modular plants to work more closely with site builders in incorporating modular sections into tract developments. Royal Plastics’ all-plastic prefabricated house was exported to more than 40 countries.

The possibility of stacking modules to create higher-density housing was boldly demonstrated in Habitat at Expo ’67 in Montreal, but proved far too costly to be viable. The first example of stackable social housing units was built in Kingston in the early 1970s. Further demonstrations of stackable modules in mid-rise configurations were built in the late ’80s and ’90s.

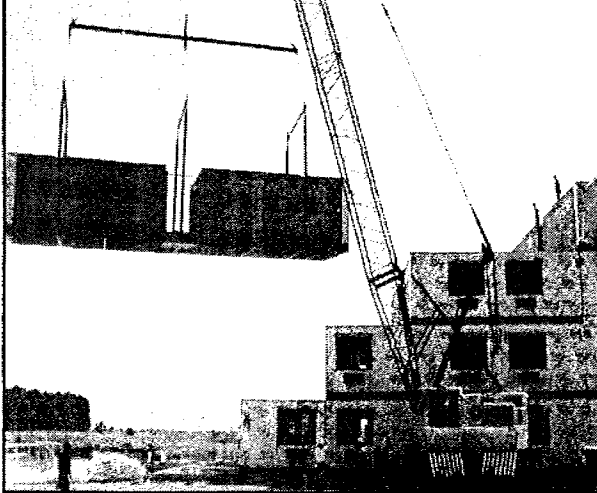
**Photo 26:**  
Factory-based house builders diversified into modular and panelized systems



**Photo 27:**  
Small entrepreneurs also ventured into modular housing. This social housing complex in Kingston, Ontario, probably the first of its kind, was built by North American Modular in 1972  
*Photo courtesy Scanada Consultants*



**Photo 28:**  
An example of mid-rise stackable modules  
from the '80s  
*Photo courtesy Canadian Manufactured  
Housing Association*



Since manufactured housing held the promise of greater affordability, it continued to be promoted by many advocates, from academics to basement inventors, as the solution to both Canada's and the developing world's housing needs. CMHC periodically funded research to assist the industry, on such topics as the potential savings from high-volume production [2], competitive strategies for "panellized" systems, opportunities for transferring Japanese, Scandinavian and American methods to Canada, and ways of linking CAD with computer-assisted manufacturing (CAM). A catalogue of industrialized construction systems was prepared in 1990 [3].

## 6. SITE BUILDERS' DRIVE FOR PRODUCTION AND PRODUCTIVITY

In all of this discussion on housing production, some basic facts must be recognized. There are no very large homebuilders and never have been: nothing like a General Motors of housing, nothing approaching even a national scope let alone international. In terms of purchasing power or clout with material manufacturers and in lobbying power, even the largest individual builders have had little weight. Neither are there any large, sustained buyers of housing, no continuing cooperatives (such as in Scandinavia) or resource industries or others who maintain longer-term commitments of reasonably predictable volume, type and quality of housing. Such buyers could help foster large, efficient, highly competitive builders or manufacturers of luxurious housing or simply great numbers of good-quality houses. The defence plant housing programs during

World War II, the veteran's housing programs after the war, and some mining ventures had constituted the large buyers who enticed the modern homebuilding and home manufacturing industry into existence. These volume purchasers have virtually disappeared.

### Initial Sources of Technological Change

Led by the larger builders, mainstream homebuilders did rather well in striving for improved production efficiency, however limited their scale and clout. The years from 1946 to the early or mid-1970s were particularly fruitful. In Table 2, some of the main changes are listed to show their apparent roots, advantages, constraints and general chronology.

**Table 2:**  
**Apparent Origins and Causes of Technological Changes in Mainstream Housebuilding**

Change in Product and or/Process	Research and Development by				Builder's Incentive to Adopt			Helped or Inhibited by	
(with approximate date of widespread acceptance)	Manufacturers of materials or components	Builders and their associations	Public sector (NRC, CMHC)	Universities	Speed with less skills and less cost	Enhance quality	Exploit public sector incentives	Building codes	Acceptance (CMHC, CCMC)
Platform frame; some tilt-up, some pre-cutting (1946)	S	S	S	S	S	S	S		
Insulation (1950)	P		P	P		P	S	S	P
Warm air heating counter-convection (1950)	P		S	S		S			
Manufactured windows with frames (1950)	P				P	S			
Transit-mixed concrete basements (mid-to-late 1950s)	P				P	S			
Manufactured cabinetry (1950s)	P								S
Plywood sub-floor and sheathing (mid-1950s)	P	S	S	S	P	S		S-D	P
Drywall interior finish (late 1950s)	P				P			P-D	
Prefab formwork basements (late 1950s)	P	S			P	S			
"Stationary assembly line" (late 1950s)	S	P		S	P		S		

**Table 2: (Continued)**  
**Apparent Origins and Causes of Technological Changes in Mainstream Housebuilding**

Change in Product and or/Process	Research and Development by				Builder's Incentive to Adopt			Helped or Inhibited by	
	Manufacturers of materials or com- ponents	Builders and their associations	Public sector (NRC, CMHC)	Universities	Speed with less skills and less cost	Enhance quality	Exploit public sector incentives	Building codes	Acceptance (CMHC, CCMC)
Roof trusses (mid-1960s)	P		P	P	P	S		P-D	P
Fork lifts, trucked hydraulic cranes, pallets (mid-1960s)	P				P				
Winter construction (mid-1960s)	P	P	P	S	S		S	S-D	P
Prefinished, low-maintenance claddings (mid-1960s)	P				P				P
Sealed double windows (mid-1960s)	S		P			P			P
Polyethylene vapour barrier (1970s)	P		S			P		P	P
Plastic drain-waste-vent (dwv) piping (early to mid-1960s)	P							S-D	P
Plastic weeping tile (early 1970s)	P	S	S		S			S-D	P
1-step floors: carpet or vinyl directly over sheathing (1970s)	S	P			P				
Higher levels of insulation and airtightness (mid-1980s)	S	S	P	S		S	S	S	S
All-plastic plumbing (1990s)	P				P			S-D	S
Plastic bath/shower units (1990s)	P							S-D	S
Computerized cost control (1990s)	S	S			P	S			
"Super" windows (1990s)	P	S	P	S		S	S	S	S
Mechanical air-handling and heat recovery (1990s)	P	S	P	S		S	S	P	S
LEGEND P = Positive and substantial influence S = Some positive influence D = Delaying or inhibiting influence									
Source: Scanada [1], updated 1996									

Reviewing Table 2, it can be seen that the great majority of productivity changes originated just outside the homebuilding industry, from the research and development hands of the materials or equipment manufacturers. Much of the earlier activity was in the United States. In the '50s and '60s, the component entrepreneurs and homebuilders were also encouraged and aided by the university research activities of the time, particularly the University of Illinois Small

Homes Council, Purdue University and the University of Saskatchewan. Public agencies became significantly involved in production research and development, especially in the late 1950s and through the 1960s and early 1970s.

Recollecting the post-war period of ferment, it is fair to say that technology transfer was pushed strongly by four parties:

- the materials and equipment sector;
- the homebuilders;
- CMHC's architects, engineers and inspectors, with especially the latter helping to train, inform and direct the post-war army of small builders; and
- the research programs at NRC's Division of Building Research and the Forest Product Research Laboratories, some of which were instigated by CMHC's technical staff and materials acceptance people, and which also influenced the most direct technology transfer vehicles, the National Building Code and Residential Standards.

Further examination of Table 2 may help illustrate the factors at work. Codes and standards, largely a creature of the public sector, may indeed have a particularly inhibiting effect in the earlier years or even decades of a technological innovation, but may then tend to be helpful in technology transfer and implementation when a change is finally in the code and adopted. In some cases, cost-saving changes were introduced to the building industry through this route. Table 2 tends to give a (falsely) positive slant to the effects of codes: it only deals with "safe" or mainstream changes that have been accepted. The table does not reveal the time frame involved, for example, the 20 years or longer that unit bathroom proponents and plastic pressure pipe producers took to gain approval of their products.

While the builders themselves tended to be cautious in adopting innovations, the incentive that moved them most effectively was the drive for increased production and labour productivity using less skilled labour as a contributor toward controlling and reducing costs and increasing profits.

Public sector involvement has extended beyond the research and development, and technology transfer functions already mentioned. The wartime and early post-war housing programs and financing mechanisms created a secure opportunity inviting larger contractors to

bring to bear improvements in production and productivity techniques such as platform framing, tilt-up construction, prefab shops and the stationary assembly line approach.

## Increased Productivity

If the single-family homebuilding industry's goal was indeed to control and cut costs while producing more, and faster, by reducing the use of site labour, especially skilled labour, the measures clearly worked. Table 3 lists some main changes and their effects.

At the same time as the distinct changes listed in Table 3 were affording reductions in labour and time, other operational changes improved efficiency and control throughout. The "stationary assembly line" approach to sequencing the subtrades house by house, the mechanical handling by forklifts and truck-mounted cranes, and the use of power tools and fasteners, particularly air hammers and screw guns, have greatly improved even those component operations where the materials and installations changed little, such as in electrical wiring, plumbing, heating and even clean-up.

Changes in on-site labour can be traced and compared if allowances for changes in product size and amenities are factored in. The benchmark is a rather typical mid-1960s two-storey house with 110 m<sup>2</sup> (1,200 sq. ft.) living space, 1 1/2 bathrooms, a generous kitchen with cabinetry and good landscaping. Its mid-1940s counterpart can be adjusted to similar standards, as can a typical house of the mid-1990s. The total hours on site reflect all the production changes listed above. For project-built houses, including site supervision and contingencies:

- Site hours numbered roughly 2,400 in the mid-1940s [2]. These were reduced to about 950 in the mid-1960s [3]. There appears to have been little improvement since then; all-plastic plumbing and unit baths allow some reduction in the 1990s.

**Table 3:**  
**Impacts of Changing Production Methods on On-site Labour**

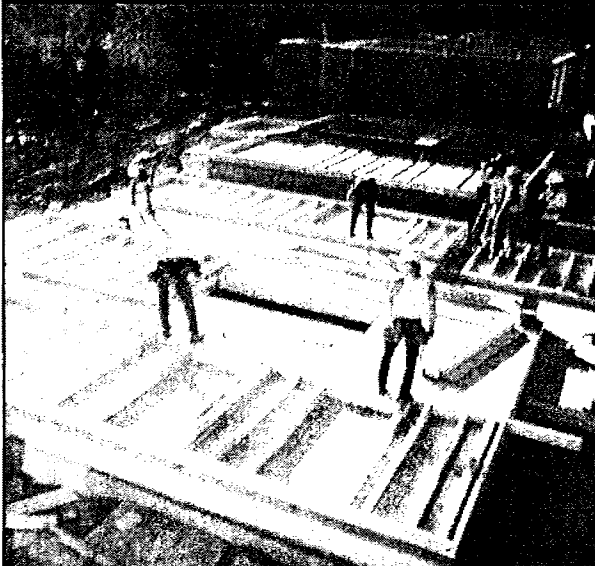
Changing This Operation	To This Operation	Reduced On-Site Labour
Framing piece by piece, in balloon construction	Platform framing using power tools	About a third or less
Constructing windows on site	Installing manufactured windows	A quarter or less
Sheathing walls, floors and roofs with boards	With sheet plywoods	A third or less
Forming basements with board formwork and site-mixed concrete	With prefabricated plywood forms and transit-mixed concrete	A third or less
Constructing cabinetry on site	Installing manufactured cabinetry	A quarter or less
Finishing interiors with wet plaster	Drywalling interiors	A third or less
Framing roof piece by piece, ceiling joists/rafters/collar ties	Framing roof/ceiling with trusses	A half or less
Brush painting interior, two or three coats	Roller painting, one or two coats	A third or less
Constructing chimneys with brick and flue tile	Installing manufactured flues	A quarter or less
DWV (drain-waste-vent) plumbing in cast iron and galvanized steel	Plastic DWV pipes	About half
Source: Scanada [1]		

- Construction time was about seven months at best in the mid-1940s, with delays in material supply being common [2]. This had been reduced to about seven or eight weeks at best in the mid-1960s [3]. Again, there has been little or no further change since then.

CMHC published the first edition of *Canadian Wood Frame House Construction* in 1967, which captured the essence of efficient platform framing techniques and served as an on-site bible for many small builders and trade apprentices [4].

**Photo 29:**

Except for detailing to increase energy conservation, the flexibility and efficiency of tilt-up walls and truss roofs meant that wood-frame construction changed little from the '60s through the '90s



## Mark Houses Reflect Changing Goals of Innovation

Despite the foregoing observations, to say that there have been no productivity improvements since the mid-1960s is untrue. The house of the 1990s had improved remarkably in its windows, insulation, airtightness, heating efficiency, finishes and maintenance requirements compared to its mid-1960s forerunner, without incurring additional on-site labour or increased schedules. The industry's change in emphasis from sheer productivity to higher performance was illustrated by the Mark series of research and development houses [5]. These experimental houses were built between 1957 and 1986 by CHBA and its predecessors in cooperation with CMHC, NRC, local builders' organizations and others to explore promising but untried housing technologies. The first Mark houses—Mark I to Mark IV—which were reviewed in the *Two Decades* report featured cost-cutting, productivity-enhancing innovations, including heated crawl space plenums, stressed skin roofs, gypsum sandwich partitions and the world's first use of wood foundations for houses.

### Mark V, 1965, Kanata

The Mark V house was undertaken as a work study to determine if costs could be further reduced by improving construction methods. Two houses were built, one using conventional techniques, the other with new techniques recommended by the NHBA's Technical Research Committee. Detailed cost and time records were

kept during construction. Results of the study showed that for the test house, materials accounted for 74 per cent of its costs, labour for 24 per cent and equipment rentals for 2 per cent. The conclusion was that the system could be improved very little overall without increasing the degree of prefabrication of house components such as cabinets and pre-hung doors.

### Mark VI, 1968, Kitchener

The Mark VI project introduced three practices from commercial construction to test their applicability in housing: precast concrete basement footing and wall panels, steel floor joists and wall studs, and radiant electric heating sandwiched between drywall panels. Mark VI also helped to introduce two new manufactured products which later became commonly used in Canada—prefabricated three piece bathroom modules and vinyl soffits, fascia, siding, eavestroughing and shutters—all reducing costs and the latter reducing maintenance.

Mark VI, then, generally signalled the end of the concentration on productivity and the beginning of concentration on housing performance, although some of the further Mark houses did address productivity. Mark VII in Vancouver continued testing the use of precast concrete for basements and also demonstrated a prefabricated T-joist stressed-skin floor system. Mark IX in Regina and Mark X in Guelph explored the greater use of steel in foundations, framing and floor systems. Performance aspects of the Mark houses are noted briefly in Part IV.

## 7. A REVOLUTION IN APARTMENT CONSTRUCTION

Typical apartment construction changed little until the late 1950s, and then in one decade or so, in growing vertically, it changed (in both production process and end product) perhaps more than the single-family house did in a full century. The term “breakthrough” is not misused at one or two points in medium- to high-rise apartment evolution. The demands and economic incentives appeared to be clear. The constraints were largely technical rather than the code or jurisdictional constraints facing low-rise housing production over the same period.

### Technology Responds to the Demand to Build Higher

Apartment developers began to build up rather than out in response to several influences: cost of land and services, new demands to have open space around structures, sharply increased demand for rental apartments in or near cities, and increasing complexities, costs and delays in getting a piece of land approved for building. By the mid-1950s, Toronto was beginning to move to medium-rise structures of seven to 10 storeys. Through the 1960s, the highrise structure of 15 and more storeys became the typical form in that area, and became common in many centres across Canada.

#### Medium-rise construction

The erection of medium-rise apartment structures required the application of materials, designs and building techniques substantially different from those used for walk-ups. Building codes limited the heights to which timber frame or masonry load-bearing walls and structures could be built. The available alternatives were structural steel framing with cast-in-place concrete floors, various materials (including masonry) for infill walls and partitions, and some form of exterior cladding; or cast-in-place concrete to form the structural shell and floors, and various materials for in-fill walls, claddings and finishes.

Photo 30:

The Lincoln Towers in Waterloo, Ontario is typical of the concrete slab, medium-rise apartments found across the country.



Because there was no need to provide clear open-span (i.e., column-free or bearing-wall-free) spaces in apartment construction, and partly because of familiarity with materials and processes, reinforced concrete construction emerged as the predominant construction type in the medium-rise and later in the high-rise segment of the apartment construction industry. The fact that span lengths could be kept to normal room sizes, and that design floor loadings were not high, meant that concrete floor slabs could be kept to reasonable thicknesses. From experience with other forms of buildings and engineered structures, apartment developers were familiar with the installation and support of formwork and placement of concrete. Union jurisdictions were perhaps additional factors in maintaining the dominance of concrete over steel systems in apartment construction.

The methods and materials used initially were those of traditional concrete construction: the use of timber and plywood to make the forms, installation of reinforcing steel according to the engineer's design and placement of concrete. Formwork for floor slabs was fabricated from



plywood and timber, and supported by a system of adjustable steel posts called vertical shores. The concrete was hoisted and deposited at the working level by either a construction crane (the early ones being the standard “crawler” cranes) or a material hoist equipped with a concrete bucket and hopper. Distribution at the working level was done using wheelbarrows on runways, to move concrete to those locations the crane could not service. The tasks of setting up and then later dismantling and moving the forms and vertical shores to a higher level for reuse were difficult and time consuming. Generally, with good concrete curing conditions, three storeys of shoring were required to maintain progress at the rate of one storey per week.

With greatly increased building activity and the use of concrete, new products were developed and introduced to the market through the 1960s to help speed the job. Horizontal shoring systems were developed to replace the use of vertical shores in certain situations. The horizontal shore was basically a reusable, extendable joist of steel or aluminum, supported on the scaffolding. Panel-forming systems were developed, patented and pressed into use. Heavy-duty shoring frame systems replaced the vertical shores. Improvements in hoist towers and hoisting equipment were introduced. Motorized concrete buggies replaced wheelbarrows. Later, concrete conveyor-belt systems and concrete pumping systems radically improved the construction process.

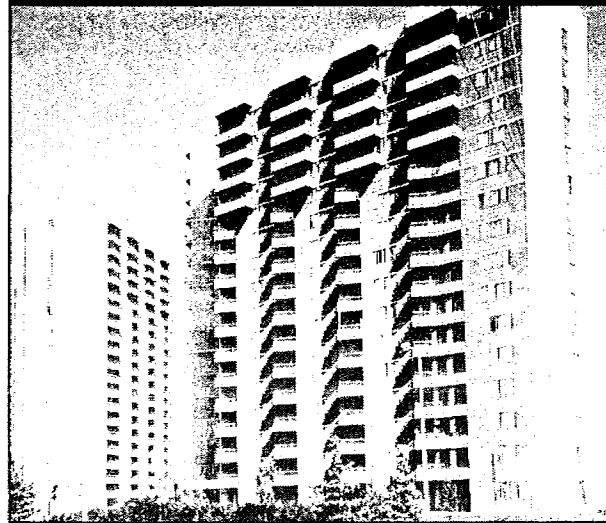
In all of this, the singular awkwardness that remained unsolved was in the movement of workers. While materials were hoisted, pumped or “buggied” with increasing speed and ease, the crew had to climb through the building or through elaborate scaffolding. The consumption of time and energy became increasingly onerous as building height increased.

### **Highrise construction**

The “need vs. opportunity” relationship between building height and construction tools was not quite clear. Were designers wanting to build higher and equipment manufacturers accordingly

devising tools to make it feasible, or did designers see the remarkable new tools and then decide to take the opportunity of building higher? Probably both forces were in play. In any case, high-rise apartment production quickly became an example of construction engineering/production engineering skills working without parallel in residential history.

**Photo 31:**  
New production methods and equipment allowed apartments to reach ever higher



Production engineering for medium-rise as well as high-rise apartment construction focussed first on the vertical transport of materials and then, in the remarkable ferment of advances in the 1960s, on the vertical transport of crew and large section formwork of the building. Beginning with medium-rise construction, material hoist towers gained widespread acceptance and use. The earlier versions were generally limited in height to about 28 metres (90 ft.), and were capable of hoisting a 550 kilogram (1,200 lb.) payload at a maximum speed of 30 m (100 ft.) per minute. This unit was well suited for the medium-rise structure and simplified to a considerable degree the process of moving materials to various levels. Materials included concrete (using wheelbarrows loaded with concrete and placed on the hoist platform, hence the name the “two barrow tower”), masonry products, windows and doors, and multitudes of finishing materials, as well as various pieces of equipment. Then a “heavy-duty

tower” was developed as a precursor of the “new tools” that came to distinguish Canada’s high-rise system.

## **New Tools Create a World-Leading System**

Three major product lines were introduced or developed in Canada in the 1960s that, together, had a major impact on high-rise apartment construction.

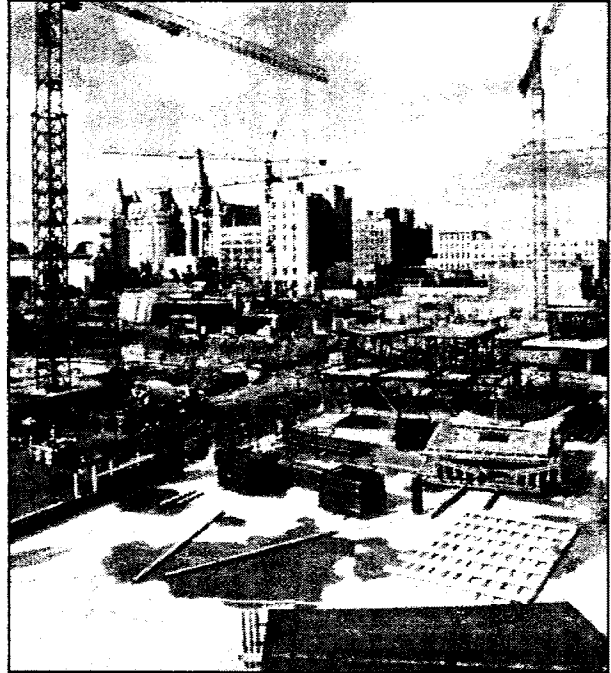
### **Tower cranes and climbing cranes**

The first important move was the introduction of tower-type building construction cranes, types that had been developed and widely used in Europe. The early models were either the “stationary tower,” guyed or attached to the side of the building or the “traveller” which moved along a track bed installed adjacent to the building. These units, in many cases, were self-telescoping, so they could extend in height as the building grew. Their other big advantage was their ability to distribute material over a broad horizontal area at the working level. Campeau Corporation in Ottawa was credited with introducing such equipment to Canada and North America. Campeau could show savings of about 35 per cent in overall concrete costs compared to the earlier method of hoisting concrete by means of a hoist tower and distributing it horizontally using wheelbarrows.

Such tower cranes were limited in working height to about 20 storeys at best. Another type of construction crane literally removed the lid on building height: the “climbing” crane. This crane used the building structure as its support base, and was jacked up to higher support levels as the building grew. Eliminating the need for a structural tower as part of the crane meant that this crane was significantly less expensive than the others, yet still offered equal or better operating characteristics. The location of the climbing crane within the confines of the building shell, usually in the elevator shaft, also provided better work area coverage than with cranes at the side of the structure.

**Photo 32:**

**Tower cranes and workers’ hoists had a profound effect on the height of both commercial and high-rise apartment construction**



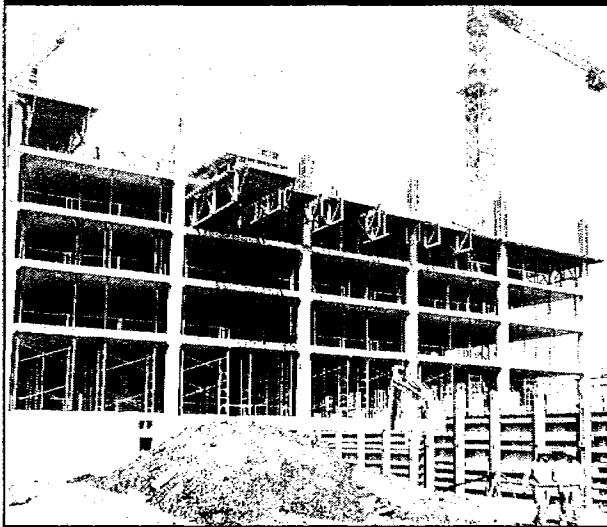
As apartment developers became more familiar with the use of cranes, further time and cost savings were realized. The prime advantage of this type of equipment, as mentioned above, is the ability to distribute materials on the working level close to the final destination. For concrete placement, this ability eliminated the need for other forms of hoisting or distribution equipment, such as wheelbarrows and buggies, requiring elaborate runways or conveyor belts.

### **Flying formwork and flat slabs**

The operating characteristics of the climbing crane, and its strategic location more or less in the centre of the work, offered another unique opportunity for the apartment builder to realize substantial time and cost savings in forming and shoring floor slabs: the development of the flying formwork concept. In this, the contractor moved large sections of shoring and forming as whole units, eliminating the need to dismantle, move, and re-erect the formwork and support system.

The flying form became the second major improvement in the radical streamlining of high-rise construction. Early problems were encountered in trying to apply the process for some building designs because of deep spandrel beams around the floor perimeter and the need to “collapse” the shoring a significant amount to provide adequate clearance under this spandrel for form system removal. The need to eliminate this obstruction was recognized, and in the mid-1960s the flat slab design was developed and applied extensively in apartment construction. With this design, the floor slab is of uniform thickness throughout. The Toronto flat slab/climbing crane/flying formwork system for apartment construction quickly became recognized throughout North America, with apartment developers coming from far and wide to observe and adopt the system.

**Photo 33:**  
Increased production resulted from using “flying formwork” where a tower crane moved whole sections of shoring and forming as a unit  
*Photo courtesy National Research Council*



### **Workers' hoists**

The third product line which came into play at this time was also developed in Canada. The “Hi-Rise” hoist tower was safety-designed and

licensed to operate as a worker's hoist. It could be erected to heights of up to 244 m (800 ft.), and carry 20 workers or 1,600 kg (3,500 lbs) at lift speeds of up to 75 m (250 ft.) per minute, in comfort and safety. If the tower was not to be used for the transport of personnel, it could be equipped with a different hoisting mechanism and material platform to carry payloads of up to 270 kg (6,000 lbs) at speeds of up to 180 m (600 ft.) per minute.

The entire combination of equipment available to the apartment developer now afforded the opportunity to apply production line operating and control techniques. The various stages of work, from initial construction through to final finishing, could be planned and scheduled on a floor-by-floor basis, with the trades and materials moving reasonably easily from one work site to the next rather than the product moving to the work station as in a factory or assembly plant.

The result was a stationary assembly line, with the line vertical. As an indication of the savings involved, the on-site labour hours consumed in constructing walk-up apartments in 1946-47 were about 2,000 hours per apartment unit [1]. By the early '70s, the better finished and serviced high-rise apartment units were being produced in about 1,000 site hours per unit [2]. The advantages of these production techniques included high productivity with both skilled and unskilled labour, design flexibility for mid- to high-rise building forms, structural integrity against progressive collapse, structural adaptability for seismic zones and amenability to thermal detailing and heating, ventilating, air conditioning provisions for any climate.

### **Continuing Developments and Innovations**

While the combination of cranes, flying formwork and flat slab construction set the standard in production efficiency for high-rise developments, continued efforts were made to introduce greater levels of prefabrication and to develop improved systems for smaller buildings.

### **European systems with higher factory content**

Canadian apartment developers were twice enticed by the possibilities of technologically advanced European systems for apartment construction.

In the first instance, the Silver Heights Development Corporation in Winnipeg used the "lift slab system" to construct apartments in the six- to eight-storey range. In this approach, the concrete floor slabs were individually cast on the ground, one on the other, with a releasing agent or separator (such as polyethylene) between the slabs. After all had been cast and cured, they were jacked one at a time, using hydraulic jacks on the permanent columns, to their final locations. The final column connections, walls, cross-bracing and other components were then secured. Partitions, plumbing, wiring, and even finishing and furnishing materials and units could be added to each floor before it was raised to its final position.

Winnipeg's Shelter Corporation developed the lift slab system further, incorporating post-tensioning with hydraulic jacks to stretch and anchor steel reinforcing cables placed in conduits through the slab. Such post-tensioning allowed thinner slabs to do the job, reducing material weight and footings. Shelter Corporation constructed six- to 12-storey apartments in this manner in the 1960s. Perhaps the anticipated cost savings never materialized (the extra engineering costs in low-volume usage possibly negated any possible savings), or perhaps the question of the lift slab system reaching to high-rise heights and high-volume production posed a problem. In any case, by the late 1960s, the low-cost, Toronto flat-slab system was taking over in the West and, indeed, through most of Canada as described earlier.

Interest in several advanced precast systems used in Europe also circulated through North America. It proved enticing to several entrepreneurs, including the leading developers and users of the flat-slab system. The northern European leaders in precast apartment building systems were achieving very high quality, with

much better detailing for cold-country performance and durability, and at lower overall costs, at least in steady high-volume production of reasonably standardized apartments. In such production, the reduction of on-site hours and a shorter financing period could more than offset the extra fixed costs of plant. In such ideal usage, it was projected in 1970 that a 10 to 12 per cent saving could be gained compared to the best on-site job methods.

System builders, such as Denmark's Larsen and Nielsen, Sweden's Jespersen, Skarne and England's Wates, were courted by apartment developers. In the early '70s, Wates became a partner with a Toronto consortium of large developers to form Modular Precast Concrete Structures Ltd. The new company acted as a precast building subcontractor to the developer partners, in competition against their own normal deployment of the Toronto flat-slab system. At the same time, the Jespersen system was brought in and adapted by an entrepreneur, under the company name Jespersen-K, to operate as an open-market, system supplier for any developer or owner, with a production plant set up in Markham, Ontario.

These European systems encompassed far more than the organization and production-delivery-erection of precast floors and walls. They also included precast stair and elevator shafts, columns, refuse chutes and ducts, stairs and landings, balconies, service core or core-wall units for bathrooms and kitchens and other manufactured components such as modular (and sometimes moveable) partitions, cabinet walls, closet walls, windows, doors and plastic drain-waste-vent sub-assemblies.

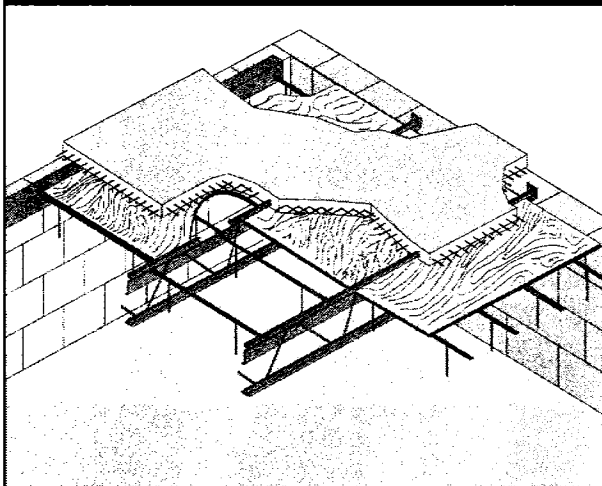
The open marketing of such an integrated system faced great difficulties in encouraging much dimensional standardization in the design of structures or in the scale of projects. High-volume pilot trials were complicated by incomplete industrial engineering work in transplanting the system into Canadian apartment designs. Costs were higher than expected and the systems could not compete against the Toronto flat-slab system.

Further, the popularity of high-rise apartment living was waning, and the construction pace finally slackened. The European-based systems were closed down by 1973.

### **Light steel and concrete composite systems**

Later in the '70s and '80s, other Canadian systems began competing with the flying-form concrete system, including light steel and concrete composite systems. Hambro was one of the leading innovators. In these systems, the formwork became a permanent part of the structure, achieving high productivity in both material and labour usage. Cold rolled steel was keyed together with cast-in-place concrete, or in factory sub-assemblies, to form floors, beams, headers, columns and walls. V-rib steel pans or clip-in panels spanned between joists to complete the floor's dual-purpose formwork and structure. Lightweight concrete could also be used efficiently with this approach. Gypsum board suspended under the joists ensured fire resistance. Both light steel and composite concrete systems substantially reduced requirements for these materials, as well as almost eliminating the use of separate formwork, welding and other redundant or labourious steps.

**Photo 34:**  
Material and labour savings resulted from composite systems, such as that developed in Canada by Hambro, where the formwork became a permanent part of the structure  
*Photo courtesy Canam Hambro*



### **Precast concrete floor systems**

Various types of precast floor systems, developed for commercial construction, were adapted for use in apartments. These were particularly cost-effective in mid-rise construction, often in combination with load-bearing concrete block walls. Most common were flat planks, which required only painting below and a topping coat of concrete and carpeting above for a finished floor and ceiling. Extruded, pre-stressed tubular core planks were first developed by Spiroll in Winnipeg in the 1960s and their use spread worldwide.

### **Brick veneer and steel stud system**

Brick has long been a popular choice for the exterior cladding of residential buildings for both its appearance and its long-term durability. Concrete masonry had been the predominant backup material used in high-rise construction since the 1950s. In the '70s, a system came on the Canadian market which used steel studs instead of concrete block to support the brick veneer. The smaller overall thickness and lighter weight of the steel studs made for economies in structural framing and foundations. Buildings could be closed in faster and in a wider range of weather conditions than with conventional masonry. Higher insulation levels could also be accommodated within the stud space without increasing the total thickness of the wall assembly. As a result of these many advantages, the system came into widespread use in apartment construction in the 1980s.

### **Exterior insulation and finish systems**

Beginning in the 1980s, combined exterior insulation and finish systems (EIFS) began competing against more traditional brick claddings. This system consisted of a thermal insulation layer—usually extruded or expanded polystyrene, but also polyurethane, polyisocyanurate or mineral wool—mechanically fastened to the wall structure, covered with a reinforced cement base coat and a colour-textured acrylic or stucco-like finishing coat. Such systems offered considerable cost advantages, as well as providing an “overcoat” of insulation over the entire structure.

**Photo 35:**  
Exterior insulation and finish systems (EIFS)  
provided competition to brick as a cladding  
material  
*Photo courtesy Gemite Products*



## 8. TARGETING NICHE MARKETS

As Canada's innovators continued to improve the wood frame house production process, they also developed systems to supplement it—but never supplant it. Their more radical innovations, touched upon earlier, have blossomed in markets for rural and cottage housing on the one hand, and remote area and export housing on the other. Some glimpses of successful innovations serving the latter two markets illustrate these activities.

### Arctic Housing: Delivering Houses to the Top of the World

Economics, not the northern environment, is the main factor shaping the design and production system for High Arctic houses and communities. Conventional wood frame houses are fairly easily designed for efficient performance in the Arctic cold (see Chapter 13 for a discussion of northern technologies) but the job of getting supplies in and building any type of house is not an easy one.

Canada's producers learned lessons in supplying the Arctic and other remote regions that helped them compete in the offshore markets. The vast distances and the short ice-free shipping season, coupled with the absence of a skilled labour pool and difficulty supplying and servicing labour dictated a production approach distinct from the construction methods of populated southern Canada.

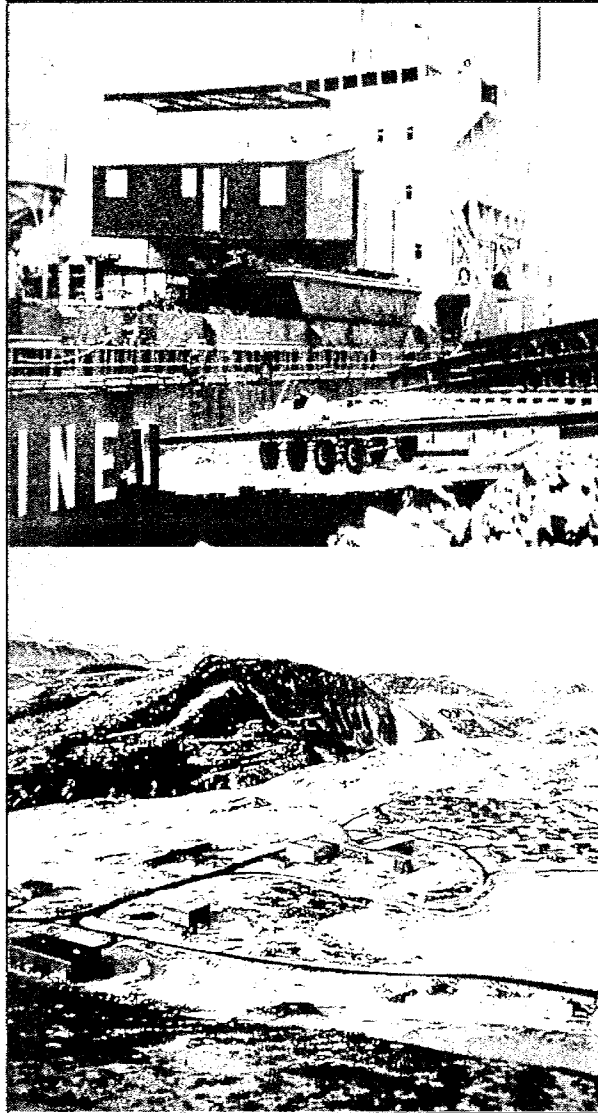
The comfort and control of a factory in southern Canada was quickly accepted as the base point of Arctic housing. High "factory-content" was initially a given. Further, prefabricated wood frame houses quickly gave way to lighter, stronger, more climate-proof stressed skin and structural sandwich housing.

However, the multiplicity of prefabricated systems available eventually created problems in terms of replacement parts and on-site repairs and adjustments, leading to a preference, particularly by the Northwest Territories Housing

**Photo 36:**

**In the High Arctic, modular housing delivered by boat helped create this mining town, Nanisivik, in the '80s**

*Photos courtesy Scanada Consultants*



Corporation, for packages of standard building materials which could be combined into a small number of different designs. Similarly, there was a trend toward standardizing mechanical, plumbing and electrical components to facilitate servicing and supplying spare parts in remote areas.

All systems, whether prefabricated or site-built, had to be lightweight, compact and rugged for shipping and winter storage, and suited for rapid erection to take advantage of the short building season.

## Export Markets: Innovations Make Their Way Around the World

In addition to exporting building materials, particularly wood products, Canadians also considered foreign market needs in their development of manufactured components and housing systems. Proven at home, at least in specialty or niche markets such as the Arctic, many technologies found success in export markets, particularly in the '80s and '90s. The following excerpts from *Canada's Exportable Housing* [1] highlight some of the more notable examples of construction systems.

### Wood composite and foam plastic sandwich panel systems

These systems combine wood-based skins, often oriented strandboard, with foam plastic cores, often expanded polystyrene, to produce high-performance structural sandwich panels for floors, walls and roofs, and even foundation walls, eliminating up to 75 per cent of the framing material required for conventional buildings.

### Light steel building systems

Lightweight galvanized steel framing can provide a complete system for house structures, offering resilience for withstanding earthquakes, dimensional stability and competitive prices, with thermal bridging disadvantages addressed by exterior insulating sheathings.

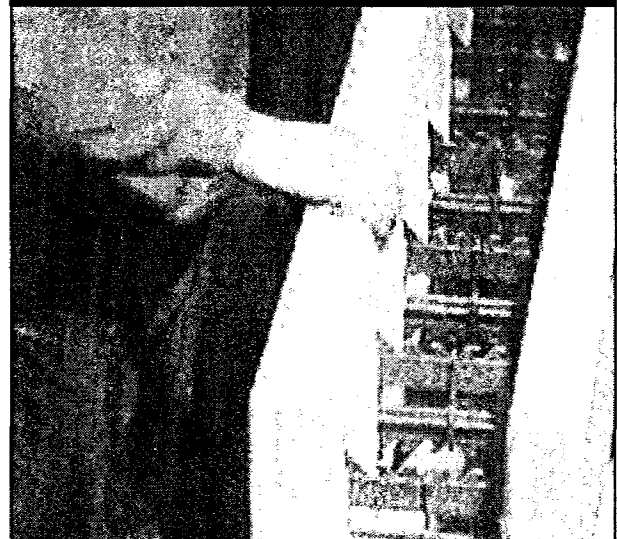
**Photo 37:**  
Light steel framing emerged as an alternative to wood in house construction  
Photo courtesy Canadian Sheet Steel Building Institute



### Permanent insulated formwork

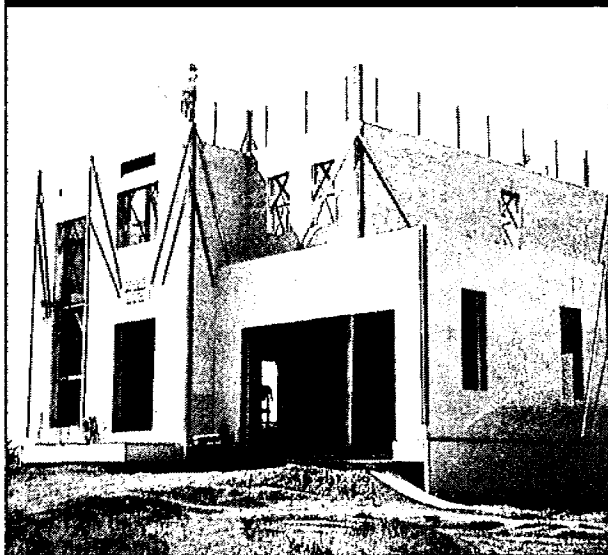
Inner and outer panels of expanded polystyrene, dry stacked and secured with tie bars, create permanent, highly insulated formwork to be filled with concrete and reinforcing steel for single-storey or multi-storey buildings.

**Photo 38A:**  
Permanent insulated formwork combined inner and outer skins of polystyrene with a core of poured-in-place concrete  
Photo courtesy AAB Building Systems





**Photo 38B:**  
**Permanent insulated formwork combined**  
**inner and outer skins of polystyrene with**  
**a core of poured-in-place concrete**  
*Photo courtesy Polycrete Industries*



### **Concrete skin and foam plastic core sandwich panel system**

Using local labour and materials, expanded polystyrene panels held in a perimeter frame of light steel channels can be quickly erected manually to form walls, partitions and roofs, which are then sprayed with a fibre-reinforced cementitious skin.

### **Reconstituted wood products**

Composite products of bonded wood fibres offer enhanced strength, stiffness, dimensional stability and shape, and make maximum use of a renewable resource. Products include laminated veneer lumber, parallel strand and "T" section joists, beams and wall studs; open-web joist systems; waterproof plywoods; structural waferboards and oriented strandboards; insulating fibreboards and hardboard claddings.

### **Roofing**

Canada's traditional mineral-surfaced asphalt shingles are complemented by new products from recycled waste materials, such as slates from recycled plastics, rubbers and cellulose, and tiles utilizing wood fibre-cement-plastic composites.

### **Windows**

Some of the world's most advanced windows are manufactured in Canada, incorporating the latest glazing technologies, insulating edge spacers, sophisticated weatherstripping and a variety of frame materials.

## **9. EMERGENCE OF THE RENOVATION INDUSTRY**

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Residential renovation blossomed in the 1970s and overtook new construction in expenditure volume in the '80s. As a housing production activity, renovation produces viable "new" houses from the existing stock, but as it is a much less systematic activity than new construction, industry-wide innovation is less apparent. On the other hand, renovation requires the highest degree of project-level innovation because renovators must constantly struggle with existing constraints to integrate new and old materials and systems.

Technological advancements were driven largely by the demand for better energy performance and higher comfort levels. These innovations in performance are discussed in Chapter 14. Innovations in productivity, while potentially attractive due to the labour intensiveness of renovation, were difficult to achieve for a number of reasons. Renovation work is shared among professional renovators, specialized trade contractors, "handyman" contractors and individual homeowners and landlords. Most of the actors in this field do not belong to industry organizations, limiting the impact of most training and technology transfer activities. For many renovation firms, most jobs are unique and never truly repeatable.

The expansion of renovation activity enticed a few large project builders, with product-manufacturing divisions, organizational abilities and success in producing new houses, to set up renovation divisions. For example, Campeau Corporation made that move in the early 1970s. However, the headaches and additional overheads of dealing with individual homeowners, their ever-changing aspirations and expectations, gave Campeau considerable cause to question the move by the end of the 1970s. Still more important was the fact that the overheads and quality control responsibilities of such a business division made it difficult to compete with the myriad army of small specialist tradespeople in the field. Campeau and other large builders bowed out.

House framers and small-scale carpenters and homebuilders also became more active in renovation markets. They were successful in the higher-quality renovation projects, but also had difficulty competing on the basis of cost with handymen/women and do-it-yourselfers. The growth of the tax-avoiding underground economy in the 1990s made life even more challenging for professional renovators.

Efforts to introduce major innovations did not achieve much success. Even the mass production of large assemblies generally proved to be an ineffective approach to renovation. For example, efforts to stack unit bathrooms in existing multi-storey tenement buildings in order to create luxurious apartments, encountered crippling difficulties and costs. While inherently less difficult, ventures to market factory-manufactured add-on rooms, such as sunspaces, generally encountered unforeseen costs, largely because existing houses offer restricted access, out-of-plane and out-of-plumb surfaces, often with wiring and plumbing hidden where least expected.

### **Systematic Upgrading**

Where systematic upgrading of the stock did occur, it facilitated more of a production line approach, bringing economies of scale and tighter scheduling. The following provide some examples.

#### **Energy retrofit programs**

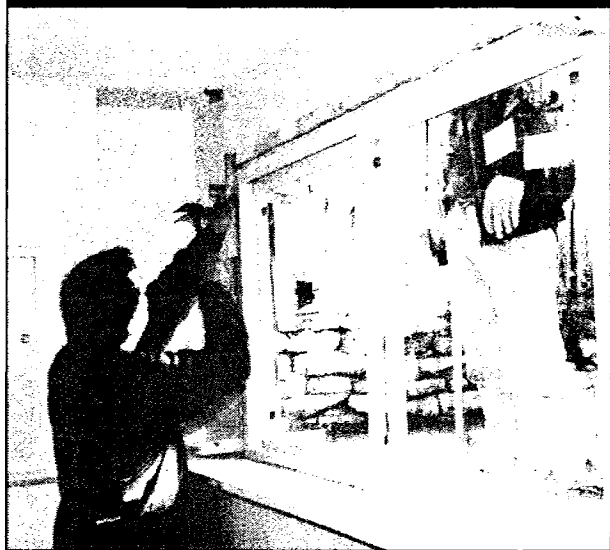
The most significant impact on renovation productivity was the systematic energy retrofitting spurred by federal subsidy programs such as the Canadian Home Insulation Program (CHIP) and the Canadian Oil Substitution Program (COSP), which were introduced in the wake of the energy crisis to encourage higher insulation levels and off-oil conversions. These, plus later provincial and utility-driven programs, created entirely new trade categories, such as air sealing contractors,

and contributed to the development of efficient techniques for reinsulating attics, insulating hidden wall cavities, airtightening envelopes and converting furnaces from oil to gas.

### **Component upgrading**

Specialist trades achieved a high degree of productivity in cost-competitive markets. Cladding replacement, initially dominated by aluminum siding in the 1950s and '60s, was carried on in subsequent decades through vinyl siding installers, who developed efficient approaches to recladding older houses and replacing soffits and fascias. Similarly, window replacement became a very profitable activity, far surpassing new installations in volume.

**Photo 39:**  
Window replacement became popular with consumers as well as a profitable component upgrade for small glazing firms



The window industry evolved in a highly decentralized fashion, with small firms buying glazing and frame components from large manufacturers, and then assembling them in their own shops on a custom basis to suit existing openings. Local kitchen cabinet suppliers/installers took a similar approach to replacing or refacing cabinetry. Re-roofing specialists also became very efficient at minimizing the time required to strip and re-shingle an existing home.

### **Basement installations**

Even before the renovation boom, considerable improvements were made to the small houses built during World War II and immediately afterward. Since many of these homes were built on crawl spaces, installing basements became a common activity. The equipment and the techniques for raising houses became refined, allowing whole neighbourhoods to be "fitted" with full basements.

### **RRAP Program**

Beginning in the early '70s, CMHC's Residential Rehabilitation Assistance Program and similar provincial programs encouraged a focus on minimum standards. This led to a more systematic approach to upgrading inadequate electrical and plumbing services, unsafe heating systems and chimneys, structural deficiencies and moisture-related deterioration, as well as achieving basic levels of energy conservation.

### **Home improvement centres**

Another source of productivity improvements and perhaps the most significant players to emerge in the '80s and '90s were the large retail supply chains, who catered increasingly to the burgeoning do-it-yourself market. The volume of sales in this area spurred the retail chains and their manufacturers to develop products, which were easier to use and install without relying on sophisticated equipment, thus simplifying renovation work not only for consumers, but also for the trades.

Examples included quick-drying adhesives and caulking, pre-hung doors, snap-together plastic eavestroughing and downspouts, adjustable closet organizers, easy-strip wallpaper, pre-mixed concretes and mortars, one-step stripping and restoration chemicals, and a variety of patching compounds. Also, the movement to water-based paints and finishes was driven largely by homeowners' desire for easy clean-ups.

Some of the more extensive chains, such as Beaver Lumber, and the mega-centres, such as Aikenhead, Réno-Dépôt and Home Depot, as well as major department stores, such as Sears, entered

the franchise installation market, building on their reputations to attract customers wary of fly-by-night renovators. Such installation work usually focussed on component replacement activities, such as re-siding, windows and cabinets.

***PART IV***

***INNOVATION IN  
HOUSING PERFORMANCE***

Canada's system of wood-frame house construction provides high-performance houses, which are durable, safe, energy-efficient, comfortable, flexible in design and efficient in resource usage. Why then would the industry's history of technological innovation shift so strongly, particularly after the 1960s, from streamlining its production to improving its performance?

This shift was partly in recognition that productivity achievements had been substantial and that the opportunities for even higher-volume production had declined. More certainly, however, the remarkable improvements in performance, which took place during this period, were in direct response to new market demands.

- Reduce callbacks and complaints to satisfy the requirements of more critical buyers and warranty programs.
- Produce energy-efficient and resource-conserving houses economically in response to perceived energy shortages and environmental issues.
- Create healthier indoor environments in response to concerns over the impact of housing on health and well-being.
- Engineer the house using a systems approach that considered the interactions among all house systems and components, in order to ensure safety and durability for occupants.
- Apply these various performance improvements to older houses to maintain the viability of the existing stock.

This shift was aided by a number of new players in housing research and development. The Housing Section at the NRC's Division of Building Research, created in 1957 in response to CMHC's request, launched the first systematic research program on wood frame housing. Disseminating the results of its research to the industry through *Housing Notes* published through the 1960s, the Housing Section

focussed on plastics and other new materials, prefabrication methods, Arctic housing systems, condensation problems, rain leakage, insulation and noise control.

When the NRC disbanded its Housing Section in 1968, CMHC filled the gap by building up its research and demonstration groups. CMHC's important role in a wide range of technical research areas, particularly indoor air quality, moisture and sustainable development, was evident in the '80s and '90s. Energy Mines and Resources established its residential research capability in the early '70s and expanded this after the energy crisis. The NRC continued to provide support to residential activities as part of its building research programs, particularly through its Energy Division in the late '70s and early '80s, as well as its Prairie and Atlantic research stations. CHBA's Technical Research Committee became the key forum for these various research agencies to interact with the industry and for deployment of collective knowledge and expertise through homebuilders across Canada.

A new breed of private sector research and development engineers emerged, starting in the late 1960s, to serve both as advisors and troubleshooters for the housing industry and as practitioners for public sector research agencies. Their firms, while generally small, helped to advance building science knowledge through extensive monitoring of house performance across Canada, field testing of new technologies, investigating problems and undertaking computer simulations.

Part IV summarizes the response, in terms of new products and building practices, to these many new demands placed on Canadian housing in the closing decades of the 20th century.

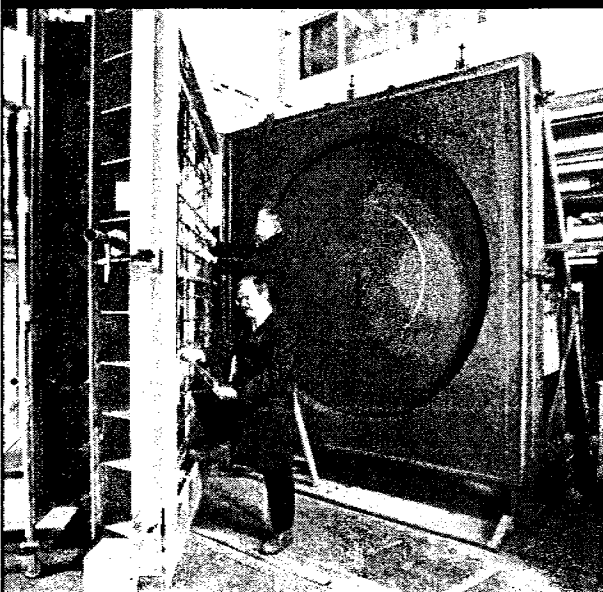
## 10. REDUCING ENERGY AND ENVIRONMENTAL IMPACTS

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Energy efficiency was probably the single most significant characteristic differentiating houses of the 1990s from those of the '60s. Improving energy performance was a major theme throughout this period and was interwoven with other themes including moisture problems, indoor air quality and sustainable development. This section first focusses on the initial period of energy-efficient technology development in the '70s and '80s. The story continues with the developments in the late '80s and '90s relating to other environmental impacts.

Early research on thermal performance by the NRC's Division of Building Research in the post-war years—much for Arctic applications or undertaken in response to CMHC's requests to investigate condensation and frost problems—led to the development of measurement techniques and a basic understanding of heat, vapour and airflows through building envelopes. However, the energy efficiency of mainstream Canadian houses in the early 1960s had not changed significantly since the pre-war years.

**Photo 40:**  
NRC's dynamic wall testing facility allows full-size specimens to be tested against water penetration under simulated conditions of wind and rain  
*Photo courtesy National Research Council*



In the mid-1960s, the electrical utilities began the modern push to improve energy efficiency. In their Gold Medallion type of programs, the utilities promoted all-electric heating on the basis of its lower first costs, while showing that annual heating bills could be kept competitive, despite the higher costs of electricity, by substantially increasing insulation levels and reducing air leaks. These programs produced the first large sample of relatively energy conserving houses, distributed across much of Central and Eastern Canada, featuring full-thickness wall insulation, greater attic insulation, flueless electric heating and more systematic attention to airtightness, particularly through the use of polyethylene as a vapour barrier.

Some of the larger developers in Eastern Canada, notably Campeau, surmised that the interests of the marketplace had been sufficiently whetted by these programs and switched from oil heating to more energy-efficient, all-electric subdivisions by the late 1960s. Similar changes did not occur in Western Canada where builders had long enjoyed the economic advantages of natural gas heating. These builders were already constructing somewhat more efficient houses due to the harsher Prairie winters and the prevalence of stucco as a more airtight exterior finishing material.

The 1972 Mark VII project in Surrey, British Columbia was one of the first demonstrations to incorporate an awareness of the importance of a sealed air/vapour barrier—in this case, structural plywood, drawing from the experience of Arctic housing—in houses with higher levels of insulation.

### **The Energy Crisis and the Search for Alternative Energy Sources**

The energy crisis of the 1970s completely changed priorities and accelerated the development and commercialization of

numerous energy-conserving technologies. It was also a catalyst for the dissemination of building science principles throughout the housing industry.

After OPEC dramatically increased the price of oil in 1973, concerns over both energy prices and energy supply led to a flurry of programs and research to improve energy performance and reduce Canada's dependence on oil. Housing, which was responsible for about 20 per cent of total Canadian energy consumption, was targeted as a sector where major savings could be made.

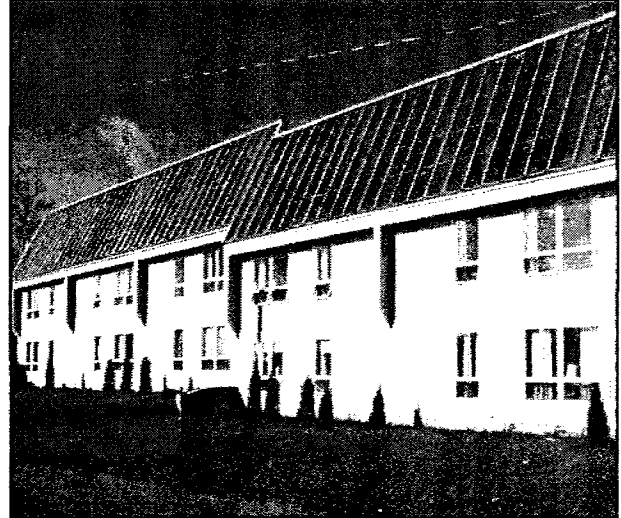
In retrospect, the energy crisis can be seen as the biggest single influence on Canadian housing development since Canada faced the challenges of creating housing and whole communities for the returning veterans of World War II.

One early reaction to the OPEC decision was to search for alternative fuel sources. With this incentive, the active solar power movement surged forward with considerable support from the federal government and was hailed by many as the answer to future housing energy needs.

**Photo 41A:**  
Early experiments with active solar systems included this example in North Saanich, B.C.



**Photo 41B:**  
Early experiments with active solar systems included this example in Charlottetown, P.E.I.



The Solar Energy Society of Canada was formed in 1974 and was active in promoting the use of renewable energy. The intergovernmental Panel on Energy Research and Development was formed in 1975 to coordinate and fund federal research. The NRC launched an extensive program in 1975 on residential solar collectors, active solar space and hot water heating systems, short-term and seasonal energy storage, solar light pipes and the durability of solar systems. Systems were installed across the country for monitoring, and a test facility was constructed in Ottawa. CMHC incorporated solar water heaters and district heating into the LeBreton Flats demonstrations.

Repeated private engineering analyses, however, showed unsatisfactory economics for active solar heating and the predictions of the 1970s concerning this energy "saviour" never materialized. Even with ongoing refinement, by the 1990s, active solar technology had only limited commercial success in niche markets, such as water heaters for swimming pools.

Passive solar energy, on the other hand, was more successfully incorporated into housing design due to its lack of moving parts. Typical new homes



could easily achieve a 20 to 25 per cent “no-cost” solar contribution to their heating needs. Early attempts in the 1970s to capture and store the sun’s energy were often extreme—a wall of tilted glass on the south and no windows on the other three sides. Often linked with passive solar was earth-sheltered housing—bermed or dug into slopes to take advantage of the thermal mass of the ground—which enjoyed a brief period of popularity in the late ’70s and early ’80s but never gained acceptance in the mainstream market. EMR took over passive solar research in 1985, focussing on high-performance windows and phase-change energy storage.

During this period, CMHC researched active and passive solar heating systems, solar mini-utilities, solar access and seasonal energy storage, and was one of the first to show that high building mass was not an appropriate approach in Canada’s cold climate. Since early solar houses did not appeal to mainstream consumers, CMHC, working with designers and builders, developed practical advice, often using graphic design aids and rules of thumb, on how to optimize passive solar energy in conventional housing [1].

CMHC studies were also undertaken on large-scale energy schemes, such as Freecool—a project to air condition downtown Toronto with cold water from Lake Ontario, cogeneration systems for public housing and northern communities, waste heat recycling and district heating. In later years, research on alternate energy sources, particularly at EMR, also included photovoltaics and ground-source heat pumps.

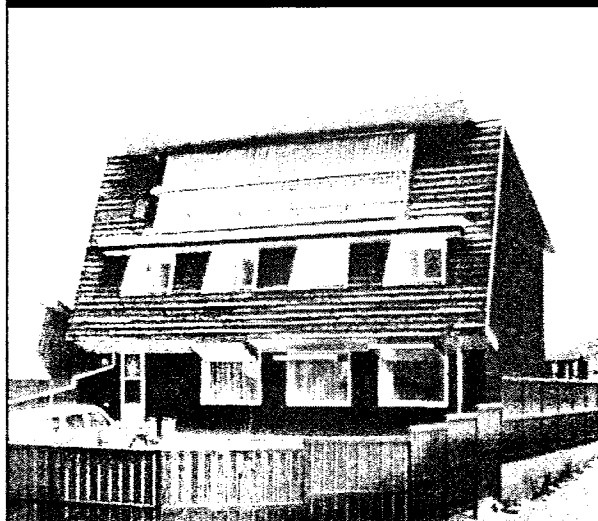
## Early Demonstrations of Energy Efficiency

The first comprehensive demonstration of super energy efficiency was, ironically, intended to showcase active solar systems. The Saskatchewan Conservation House, built in Regina in 1977, is considered to be the cornerstone of Canadian low-energy housing, incorporating virtually all of the concepts, which later characterized R-2000

and other programs. This demonstration home was a collaborative effort involving the Saskatchewan Research Council (SRC), NRC’s Prairie Research Station, HUDAC (CHBA) and several provincial agencies and universities.

**Photo 42:**

**In 1977, the Saskatchewan Conservation House in Regina incorporated almost all of the concepts used later in the R-2000 program**



The Conservation House reduced energy consumption to less than 15 per cent of that of a conventional Prairie house of that time—and this was without the use of the vacuum-tube solar collectors, which never really worked well. The home featured the Canadian “light and tight” approach to passive solar design, incorporating a modest amount of south-facing glazing and an airtight, super-insulated envelope (as opposed to the more common “mass and glass” approach of that time using extensive south windows and large amounts of thermal mass to store the heat).

Incorporated into the demonstration were numerous innovations. A double stud wall allowed RSI 7 (R40) insulation. High levels of insulation were also provided in the attic and crawl space. Insulating shutters optimized passive solar gains from the windows. One of the first attempts to create a continuous airtight envelope—through the use of 6 mil (2 mil was the norm) polyethylene and acoustical caulking—reduced

air leakage to only 1.3 air changes per hour when tested at 50 pascals of depressurization or less than a 10th of an air change under ambient conditions. Recognizing the potential impact on indoor air quality and the energy penalty associated with mechanical ventilation, a prototypical air-to-air heat exchanger—the forerunner of heat recovery ventilators—was developed. A prototypical waste water heat recovery system was also demonstrated.

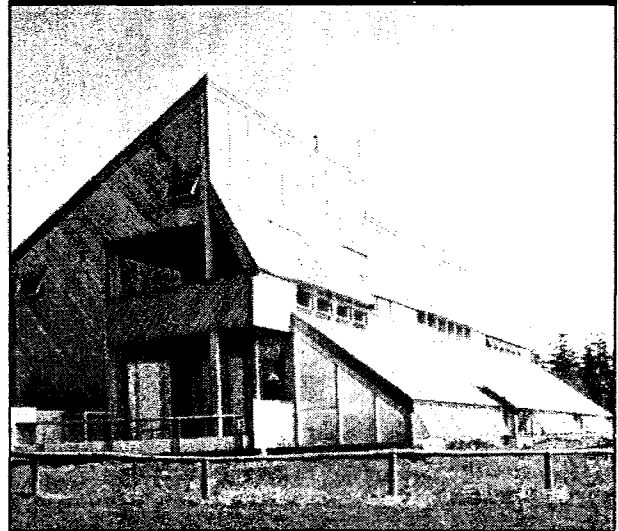
The Mark XI Project, built outside of Ottawa in 1977 was the most extensive energy research effort initiated by the housing industry in Canada to that date. Four nearly identical single-detached houses were built side by side in order to determine the cost-effectiveness of various energy conservation techniques. Technologies tested included active solar heating systems, air source heat pumps, domestic hot water preheat systems, airtightness methods, varying amounts of insulation beyond current code requirements and controlled ventilation. The NRC's extensive instrumentation was the first example of year-round, energy-performance monitoring.

**Photo 43:**  
The four Mark XI houses were used for comprehensive energy conservation studies  
*Photo courtesy National Research Council*



Another significant demonstration at that time was the 1978 Ark in Prince Edward Island, which not only made extensive use of active and passive solar, but strove for a greater degree of autonomy, even providing food sources through greenhouses and fish farming. This approach, however, was regarded as less applicable to mainstream market housing.

**Photo 44:**  
The Ark in Prince Edward Island went beyond the use of active and passive solar to the production of food in its greenhouse and fish tanks



Based on the success of the Saskatchewan Conservation House, the federal and provincial governments co-funded the Energy Showcase of Homes in Saskatoon in 1980 to demonstrate that low-energy homes could be built with consumer appeal. The key feature of the project was the use of a performance target for space heating which allowed teams to construct 14 houses using whatever systems and techniques they preferred, such as Trombe walls, the use of a high-efficiency water heater for space heating, quadruple-glazed windows, window insulation schemes or super-insulated walls. This performance-based approach required the development of a computer simulation model to predict energy performance, which then became the basis for the NRC's development of HOTCAN, which, in turn, was evolved by EMR into HOT-2000, the main

energy simulation tool of the Canadian home building industry.

## The R-2000 Program

In that same year, 1980, Energy Mines and Resources announced the Super Energy-Efficient Houses (SEEH) Program as part of Canada's National Energy Program. EMR began with research and pilot testing, building on the experience of the Saskatchewan Conservation House and the Energy Showcase, and working in partnership with the CHBA. Builders across Canada constructed a series of pilot SEEH units in 1981, which EMR monitored closely. Promising results led to the formal commercialization of the R-2000 Home Program in 1982, with primary responsibilities for delivery being contracted to the Canadian Home Builders' Association in 1984.

ventilation and durability. The CSA F326 standard, sponsored by EMR and supported by CMHC research, had a major influence on building codes and practices. R-2000 technical requirements were performance-based, rather than prescriptive, allowing builders considerable flexibility. HOT-2000 software was used to assess the performance of proposed R-2000 houses, and the continual upgrading of HOT-2000 made Canada a world leader in the field of residential energy analysis.

By the time the R-2000 Program was fully commercialized, world energy prices had dropped and many agencies were cutting back on energy research and programs. By the late '80s, R-2000 marketing focussed far more on the quality of construction than on energy efficiency. While the total number of registered R-2000 homes (about 8,000 by 1995) may have fallen short

**Photo 45:**  
Many R-2000 homes are indistinguishable from their less energy-efficient neighbours  
*Photo courtesy Canadian Home Builders' Association*



The primary characteristics of R-2000 technology included high levels of insulation, airtightness, balanced continuous mechanical ventilation with heat recovery, passive solar design and efficient heating systems. The technical requirements incorporated a systems approach to airtightness,

**Photo 46:**  
By design, some R-2000 houses take particular advantage of passive solar gains through south-facing glazing  
*Photo courtesy of Canadian Home Builders' Association*



of expected targets, the indirect impact of R-2000 on mainstream housing, through the Program's influence on builder practices and code development, was very substantial: a comprehensive evaluation estimating the indirect

energy savings to be more than 60 times the direct savings [2]. R-2000's integrated approach to research and development, performance requirements, builder training and quality control contributed greatly to upgrading the skill levels and building science awareness of the entire housing industry. Of particular importance was the development and ongoing refinement of the *R-2000 Builders' Manual* (later called simply the *CHBA Builders' Manual*) [3]. The energy efficiency of conventional new housing improved by over 30 per cent from 1982 to 1994 as a result of the influence of R-2000.

The Flair Homes Energy Demo (which was also CHBA's Mark XIV project) served as a major testing ground for R-2000 technologies from 1985 to 1990. Twenty nearly identical and similarly oriented houses were built in Winnipeg with various envelope and mechanical systems to allow an evaluation of their relative performance and incremental costs [4].

Complementing EMR's activities at this time, CMHC undertook extensive field monitoring of new technologies, such as air-to-air heat exchangers, external basement insulation, air sealing techniques and "dynamic" walls, and of some of the earliest energy-efficient subdivisions, such as Tumbler Ridge in British Columbia and Apple Hill near Ottawa. Such field work also led to a much greater understanding of moisture and air quality problems, leading to recognition of the importance of a systems approach to energy conservation. Several detailed publications were written for builders on energy-efficient construction practices [5]. CMHC also devoted resources to energy analysis software development. A computer system for modelling the energy-conserving characteristics of low-rise housing units—CMHC/2—was initiated to integrate energy analysis and cost data in order to recommend optimized strategies.

Similarly, the NRC undertook considerable supportive research on air leakage measurement and control, basement heat loss, and window and wall thermal performance. Provincial energy ministries and various agencies also launched energy-efficient demonstrations and research.

**Photo 47:**  
A skylight is prepared in NRC's large window chamber which can test condensation and thermal resistance to temperatures as low as -400C  
Photo courtesy National Research Council



## A Wealth of Energy-Efficient Technologies

The R-2000 energy efficiency program, various retrofit programs, plus the wealth of research undertaken by EMR, CMHC and the NRC, led to the development of many innovative technologies in the '70s and '80s. In addition to the active and passive solar energy systems mentioned earlier, the following paragraphs highlight some of the most important energy-efficient technologies.

### Advanced framing techniques

Traditional 2 x 4 in. (50 x 101 mm) wood frame construction made it relatively easy to progress from the minimal levels of insulation found in pre-war houses to the well-insulated electrically heated homes of the 1960s. However, going beyond these levels meant rethinking both basic concepts and detailing [6].

To provide greater insulating depth in walls, various techniques were explored, including strapped walls, double stud walls, 2 x 6 in. (50 x 152 mm) studs and wall trusses. The additional labour component made some of these techniques too costly for mainstream housing, but 2 x 6 in. (50 x 152 mm) framing became standard practice in many provinces. Thermal bridging at exterior corners and exterior/interior wall intersections was reduced through fewer studs and the use of drywall clips. Another weak area—headers—was improved by recessed headers and exterior rigid insulation or by modified balloon frame techniques in which the floor joist header is attached to the wall framing rather than bearing on the top plate. It was not until after the 1994 R-2000 changes that code requirements recognized the deficiencies caused by 2 x 6 in. (50 x 152 mm) framing.

While conventional roof trusses posed few restrictions to increased attic insulation, certain details required refinement. High-heel trusses, which accommodated both increased levels of insulation and attic ventilation baffles at the ceiling/wall intersection, became standard.

**Photo 48:**

**“High-heel trusses” allowed increased insulation levels and attic ventilation baffles at the ceiling/wall intersection**

*Photo courtesy Canadian Home Builders' Association*

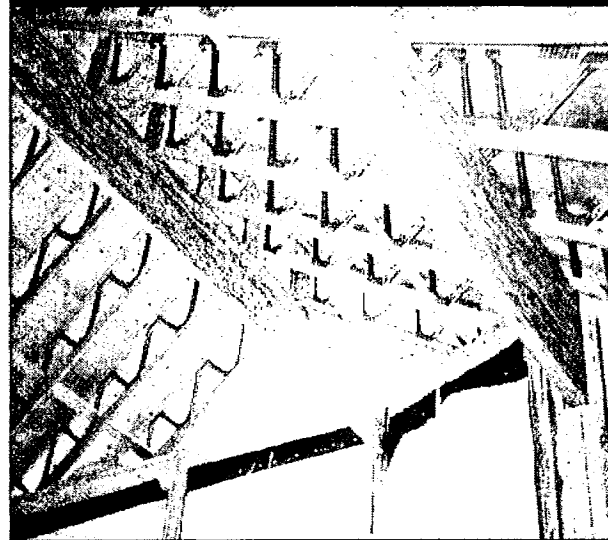


Engineered roof framing, most commonly I-joists, allowed insulation to be increased economically in cathedral ceilings.

**Photo 49:**

**Engineered roof framing, such as this combination of steel and wood, permitted an economical increase in cathedral ceiling insulation**

*Photo courtesy MacMillan Bloedel Building Products*



### **Air leakage control**

Typical houses of the 1960s, while somewhat more airtight than pre-war housing due to their use of plywood, gypsum board and vapour barriers, were still quite leaky—typically five to six air changes per hour when tested at 50 pascals of depressurization. The subsequent evolution of air-sealing techniques was dramatic, and despite the fact that airtightness could only be indirectly mandated in building codes, air leakage in conventional new houses was halved to 2.5 to 3.0 air changes per hour at 50 pascals by the 1990s and reduced to 0.75 to 1.5 air changes per hour at 50 pascals in R-2000 and other energy-efficient homes. In fact, the concepts of airtightness were so well accepted by home builders that a 1989 survey found that the air change rates in new Canadian homes, as required by the 1990 National Building Code, could not be met without mechanical assistance [7].

This evolution was driven by the performance requirements of the R-2000 Program and by moisture research, particularly at the NRC's Prairie Research Station and the Saskatchewan Research Council, which demonstrated the importance of installing a continuous air barrier rather than the accepted practice of a discontinuous vapour barrier. Initial improvements in air barrier technology included the upgrading of polyethylene thickness from 2 mil to 6 mil, combined with the development of sealing techniques for details, such as wrapping headers and window frames, installing polypanes behind electrical boxes and closing wall and ceiling penetrations. Interior strapped walls permitted electrical wiring to be

**Photo 50:**

Wet and mold-stained insulation, as in this metal stud high-rise wall, highlighted the need to control air leakage by using a continuous air barrier



run without penetrating the polyethylene. With increased research on the air permeability of materials and assemblies, particularly by CMHC and the NRC, the air barrier began to be thought of as a system rather than as a specific product, and a variety of technologies emerged. The airtight drywall approach (ADA), using caulking and gaskets to seal standard gypsum board to framing components to make a continuous air barrier, proved to be as effective

as sealed polyethylene. ADA was tested under Alberta's Innovative Housing Grants Program, which also demonstrated the use of vapour barrier paints as an alternative to polyethylene, and resulted in the development of a Canadian General Standards Board standard for acceptable paints.

House wraps of spun-bonded polyolefin, originally developed as a water-shedding yet vapour-permeable weather barrier, were modified to meet the requirements for air barriers. Applied over the exterior sheathing or factory-laminated to exterior insulation or fibreboard, house wraps became standard practice in many areas. There was much debate over the need for air barriers to be structurally supported. CMHC pioneered the EASE approach (exterior air system element) which involved sandwiching house wraps or polyethylene between layers of fibreboard to achieve structural support. CMHC and the NRC undertook extensive testing of air barrier materials, assemblies and joint details.

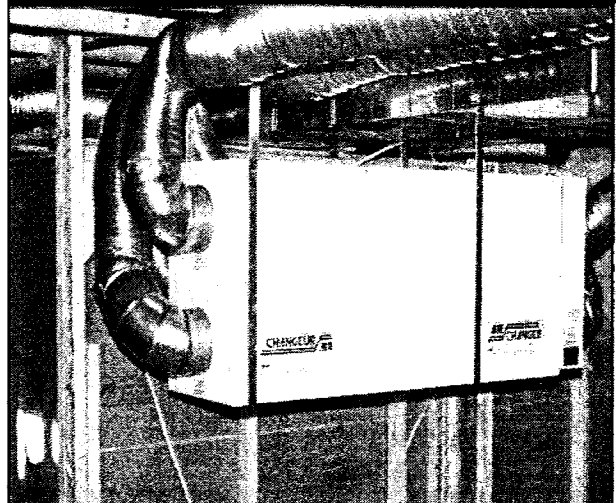
### **Heat recovery ventilators**

The development of heat recovery ventilators (HRVs) was a major success story for Canadian technology. Spurred by R-2000 requirements

**Photo 51:**

Heat recovery ventilators are a major success story for Canadian technology. They became common in new construction in the '90s

*Photo courtesy Terry Robinson*



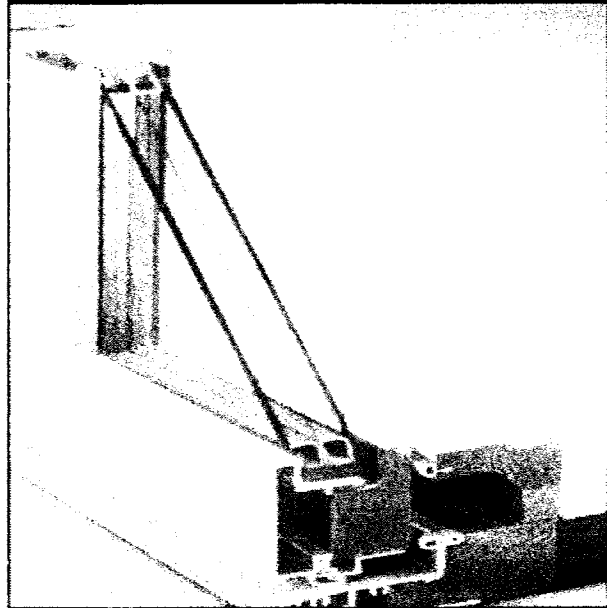
for mechanical ventilation with heat recovery to compensate for more airtight construction and by considerable research and standards development work at EMR, the original hand-built demonstration of an air-to-air heat exchanger in the Saskatchewan Conservation House evolved into a major Canadian manufacturing industry, with 50,000 units exported per year. Early problems with frost buildup and fan noise were overcome. With more stringent ventilation requirements entering building codes in the 1990s, HRVs became commonplace in new housing throughout the country.

### **Super windows**

As walls and ceilings became better insulated and airtight, it became increasingly clear that windows were the weak link in the building envelope, with standard double-glazed windows accounting for some 30 per cent of the heat loss from a typical house. Window research, therefore, became a priority and shifted to EMR after the closure of the NRC's Division of Energy in 1984.

Two major innovations were introduced in the early '80s. Low-emissivity or "low-E" coatings permitted light to pass through the window by transmission, but reduced the loss of heat back to the outside. Inert gases, such as argon, were used to fill the air spaces between panes, greatly reducing convective heat losses from air circulation. These two advancements more than doubled the thermal resistance of conventional windows at minimal additional cost. This allowed major inroads in the marketplace by the 1990s. Triple glazing became more common, particularly in Manitoba and in the North. Other multiple glazing strategies used one or two films of polyester between the panes to reduce overall thickness and cost. Later advancements focussed on insulating edge spacers and thermally improved frames, such as insulated fibreglass.

**Photo 52:**  
"Super windows" used different approaches to improve energy performance. This example incorporates a layer of polyester between the panes of glass to create a "triple glazed" assembly



Canada's development of an energy rating (ER) system, combining thermal resistance, solar gains and air leakage, provided buyers with a simple way to compare window performance and highlighted the fact that high-performance windows—unlike even the best-insulated wall—were net energy gainers rather than energy losers. Computer programs such as VISION and FRAME, developed with the assistance of EMR and the NRC, were integral to advancements in glazing and framing systems, allowing detailed modelling of new technologies.

More exotic technologies were also researched and demonstrated, such as thermochromic and electrochromic glazings which can change their optical properties, aerogel transparent insulations and evacuated glazings, but these remained some years away from commercialization.

### **Forced draft and sealed combustion appliances**

To increase energy efficiency and avoid the spillage of combustion gases indoors, many improvements were made to naturally aspirated furnaces and hot water heaters (devices in which the products of combustion leave the house through a chimney). These improvements were spurred by the R-2000 Program, which did not allow naturally aspirated appliances, and by CMHC's extensive research on combustion spillage. Induced-draft, mid-efficiency gas furnaces, with efficiencies in the order of 80 per cent, captured a significant portion of the market. Sealed combustion, condensing gas furnaces raised efficiencies to about 90 per cent but enjoyed less market penetration because of higher costs. Sealed combustion and some induced draft units eliminated the need for a chimney. They exhausted their combustion products through side wall vents, although this led to some serious problems with vent pipe failures in the 1990s. Similar efficiency and venting advancements took place, although more slowly, with gas-fired hot water heaters and oil-fired furnaces.

### **Advanced wood heating**

Wood heating enjoyed a renaissance through numerous advances in wood combustion technologies, many aided by research at EMR's CANMET (Canada Centre for Mineral and Energy Technology) labs. Traditional open fireplaces—romantic, but very inefficient and prone to spillage—were superseded by factory-built inserts with glass doors and convective air circulation. The provision of combustion air supply to fireplaces was a controversial issue, initially added to codes in the 1980s but then withdrawn. Improvements in wood stoves were more dramatic, involving baffle systems for more complete combustion, catalytic converters, dampers and airtight glass doors, making wood stoves a viable primary heat source, particularly in rural areas, and greatly reducing outdoor emissions. Combination systems were also developed, such as Hydro-Québec's by-energy wood/electric furnaces.

**Photo 53:**

The efficiency of traditional open fireplaces was improved by the development of fireplace inserts with airtight glass doors



### **High-performance insulations**

The variety of insulations available in the marketplace increased by an order of magnitude over the 1960s selection. A major advancement was the refinement of insulated sheathing boards, either of foamed plastic or semi-rigid fibreglass, which increased wall R-values without thicker framing. Similarly, foamed plastic and semi-rigid fibreglass panels were adapted for use below grade as exterior basement insulation, providing not only thermal resistance, but improved moisture protection.

Ongoing research and development by manufacturers in a competitive market led to higher R-values per thickness for most insulations. New types of foam insulations, such as isocyanurates, entered the market. Cellulose technology evolved, allowing applications in wall cavities, and dense-pack cellulose offered air barrier advantages, as was demonstrated under Alberta's Innovative Housing Grants Program in the late 1980s. When the NRC documented that convection currents due to improperly fitted batts were reducing in situ thermal resistance, industry responded by developing batts with "springy" edges to fill wall cavities completely.



**Photo 54:**  
Traditional fibreglass insulation was challenged by new products such as isocyanurate foams  
*Photo courtesy Icynene Inc.*



### **Integrated mechanical systems**

The need to integrate space heating, hot water, cooling, ventilation, heat recovery, energy storage and even appliances was widely recognized in the '80s as the next logical step in improving the efficiency and performance of mechanical systems [8]. While most early demonstrations proved overly complicated for commercialization, combination gas-fired space and hot water systems, often employing a fan coil for forced air distribution, began to gain a market foothold.

### **Heat pumps and earth energy**

By the late 1980s, residential heat pumps had emerged as a viable alternative to conventional heating and cooling, particularly in areas where natural gas was not available. The air-source heat pumps popular in the United States were less appropriate in Canada's colder climate, and so research at the NRC and EMR focussed on ground-source systems, including the development of compact coiled ground loops to reduce costs. While initial costs and ongoing maintenance costs have kept market penetration modest, earth energy systems reached the status of a mature technology. Improved heat pumps, with reliable coefficients of performance (COPs) in excess of 3.0, also played an important role in the development of integrated mechanical systems.

### **Efficient fans and motors**

Demonstration projects in the 1970s and '80s often struggled with very large "parasitic" losses from fans and pumps. Investigations by CMHC researchers found that many residential motor fan sets were only one to five per cent efficient. Benefiting from developments in the commercial sector, residential equipment began to incorporate higher efficiencies, such as through electronically commutated motors (ECMs), direct current motors and more aerodynamic rotor design. Powerful, quiet, energy-efficient fans gradually began making market inroads.

### **Energy-efficient lighting**

While not nearly as significant an energy load as in commercial buildings, residential lighting benefited from the extensive research undertaken by manufacturers and utilities to reduce peak electrical loads through improved efficiencies. Compact fluorescent and halogen lighting, which reduced energy consumption by 75 and 40 per cent over incandescent, achieved market acceptance in low-rise applications. T-8 fluorescent lamps, specular reflectors and electronic ballasts replaced conventional fluorescent fixtures in apartment common areas. High-pressure, low-voltage sodium lamps became common for exterior lighting. Dimming and control technologies improved dramatically.

### **Efficient HVAC systems for high-rise apartments**

Spurred by comfort complaints and fuel price differentials, innovations began to appear in high-rise HVAC systems. Various strategies for providing controlled mechanical ventilation to suites were explored, including downscaled HRVs. Heat recovery systems were developed to centrally extract waste heat from exhaust air, greywater and equipment rooms. Energy management control systems developed for commercial buildings also found application in high-rise residential projects. The high costs of electricity in comparison with natural gas led to an exploration of distributed gas systems. Some approaches piped gas to each suite, where small combination units provided hot water and space heating. Other approaches maintained a central heating plant, with individual hydronic loops for suites providing local control and metering. CMHC sponsored studies and demonstrations of small gas-fired cogeneration systems to provide the bulk of heating, cooling and electricity needs in apartment buildings.

### **Home automation systems**

The rapid advances in microprocessor and communications technology led to home applications. Starting with the Smart House consortium in the United States in the mid-1980s, various home automation systems were developed—CEBus being the most popular in Canada—to control and coordinate security and entertainment systems, heating, cooling, ventilating, lighting, appliances and communications. Energy management and indoor air quality were recognized as two key areas where home automation could play an important role [9].

### **Photovoltaics**

Continual improvements in the performance and costs of photovoltaics (PV) meant that small photovoltaic systems became feasible sources of electricity in off-grid applications and in low-energy demonstrations. Battery storage, however, remained problematic and costly. Equipment-specific applications also appeared in the marketplace, such as PV-powered exterior lighting.

### **Energy-efficient appliances**

NRCan's EnerGuide ratings encouraged consumers to select more energy-conserving household appliances. Leading-edge models provided breakthroughs in energy use, particularly for refrigerators where annual energy consumption could be cut from 1,000+ kilowatt-hours per year (kWh/year) to under 250 kWh/year, although such appliances remained too expensive for significant market penetration. Dishwashers and clothes washers were also redesigned to consume less water. Despite these improvements, a CMHC study of the true energy needs of appliances and other house systems found that most residential functions had "absolute" efficiencies of 10 per cent or less [10].

### **Demonstrations of Sustainable Housing**

Interest in residential energy conservation declined in the mid-1980s, largely due to the fall in world oil prices. However, by the end of the decade, energy was again a hot topic, this time as part of a much broader concern over global warming due to greenhouse gases. The release of the 1987 report, *Our Common Future* [11], by the UN World Commission on Environment and Development sparked an intense examination of all the environmental impacts of housing, leading to a comprehensive approach to making housing more "sustainable" [12].

This drive for sustainability—balancing environmental concerns, economic vitality and societal well-being—provided the impetus for the development of a host of new housing technologies and also for the integration of building science principles emerging from decades of research. Aspects of sustainable development relating to community planning and design issues are outlined in Chapter 3.

CMHC and EMR/NRCan focussed their efforts on national demonstration programs: the Healthy Housing Design Competition and the Advanced Houses Program, both undertaken in partnership with the Canadian Home Builders' Association and the IDEAS Challenge.

## Healthy Housing

In 1991, CMHC launched the Healthy Housing Design Competition to encourage the development of more sustainable house designs [13]. The key elements of the comprehensive technical requirements included:

- occupant health: indoor air quality, water quality, lighting, noise and radiation;
- energy efficiency: embodied energy, building envelope, HVAC efficiency, renewables and peak demand;
- resource efficiency: material usage, construction waste management, water conservation and durability;
- environmental responsibility: emissions, waste water, community and site optimization, and hazardous materials; and
- economic viability: affordability, impact on the construction industry, adaptability and marketability.

From 80 entries and 10 finalists, two winning projects emerged and were subsequently demonstrated. Both were examples of modestly sized infill housing to enhance affordability and promote urban intensification.

The Vancouver Healthy House, built in 1992-93, focused on creating a healthier indoor

environment through low-emission interior finishes, detailing to eliminate moisture problems and a sophisticated ventilation and filtration system. This project also consumed only one quarter of the energy of a typical house and its building materials required 60 per cent less embodied energy than conventional construction. A travelling exhibit to promote the features of healthy housing designs toured the country for two years.

The major goal of the Toronto Healthy House was to be completely autonomous from municipal services. Numerous regulatory obstacles had to be overcome before it was constructed in 1995-96. Built as a semi-detached unit beside a more conventional unit for comparative purposes, the Toronto demonstration obtained all its water from rain and snow, recycled greywater for non-potable purposes and treated its own waste water. Photovoltaic panels with battery storage provided electricity. Space heating and water heating needs were designed to be satisfied through active and passive solar gains with an auxiliary co-generator to provide backup heat and power. Due to a number of project constraints, the cogenerator was not installed at the time of construction.

**Photo 55:**  
The Vancouver Healthy House consumed only a quarter of the energy of a typical house



**Photo 56:**  
The Toronto Healthy House collected and processed its own water as well as making use of active and passive solar technologies



## Advanced Houses

In parallel, EMR (which was renamed Natural Resources Canada during this time) sponsored the Advanced Houses Program to fast-track the adoption of “green” technologies, maintain Canada’s leadership in energy-efficient housing and field test performance requirements which could feed back into the R-2000 Program.

This program was based on the success of EMR’s, and the industry’s, first attempt at producing a second generation of low-energy houses—the Advanced House built in 1989 in Brampton. This house halved the R-2000 energy budget, featured an innovative integrated mechanical system and was one of the first demonstrations to also incorporate efficient lights and appliances, water conservation and low-toxicity materials.

The 10 Advanced Houses, which were built from 1992-94, represent one of the most ambitious demonstrations of energy-efficient houses ever undertaken internationally. The projects included the British Columbia Advanced House in Vancouver, the Saskatchewan Advanced House in Saskatoon, the Manitoba Advanced House in Winnipeg, the Waterloo Green Home, the NEAT Home in Hamilton, the Innova

House in Ottawa, Maison Novtec and Maison Performante in Laval, the EnviroHome in Halifax and the Prince Edward Island Advanced House.

The Advanced Houses were required to meet 50 per cent of the R-2000 energy target and to address many environmental criteria, such as water conservation, waste management, pollutant source reduction and use of recycled materials. In total, more than a hundred innovations were developed or incorporated. The most promising included high-performance windows, advanced gas-fired integrated mechanical systems, exterior air barriers, efficient motor/fan sets, advanced oil heating, engineered wall framing and small-diameter, high-velocity ducting [14].

## “Green” impacts on other programs

Both the Healthy Housing and Advanced Houses initiatives received considerable international acclaim, particularly at the Innovative Housing ’93 Conference in Vancouver, which brought together participants from almost 30 countries to discuss energy-efficient and environmentally responsible housing [15]. Both programs also had an impact on mainstream Canadian housing. CHBA’s EnviroHomes, incorporating a full range of healthy housing principles into R-2000 homes, were built in many provinces and were well received by the public. CMHC funded a study on applying energy-efficient and environmental principles to McGill’s popular Grow Home concept. The R-2000 technical requirements were refined and expanded in 1994 to include a selection of indoor pollutant source control measures, water conservation, lighting and appliance efficiency, a selection of other environmental measures and more stringent energy targets. Utility-sponsored, demand-side management programs and provincial “green communities” initiatives began incorporating water conservation, waste management and other environmental aspects. Alberta’s Innovative Housing Grants Program assisted the development of a generic sustainable house, which was subsequently built in Calgary.

**Photo 57:**  
The Winnipeg, Manitoba Advanced House was one of a series built by Natural Resources Canada to demonstrate energy-efficient and environmentally responsible techniques



## **IDEAS Challenge**

In recognition of the lack of technical progress in high-rise apartments, particularly in contrast with the considerable evolution of low-rise housing, CMHC focussed increasingly on the high-rise sector through the late 1980s and '90s. This led to the IDEAS Challenge (Integrated, Durable, Energy-efficient, Affordable Solutions) in 1994-95, a design competition to encourage higher-performance apartment construction. Launched in partnership with NRCan's C-2000 Advanced Commercial Buildings Program, the technical requirements of the IDEAS Challenge encompassed a broad range of issues, including more durable and airtight envelopes, energy efficiency, indoor air quality and ventilation, environmental impact and resource conservation, plus accessibility and adaptability. Five regional winners emerged, with the eight-storey Le Clos St-André condominium in Montréal being the first to be constructed [16].

**Photo 58:**  
Le Clos St-André, an eight-storey condominium in Montreal, Quebec was one of five regional winners of the IDEAS challenge held to encourage high-performance apartment construction  
*Photo courtesy Sandra Marshall*



## **Emerging Sustainable Technologies**

Many of the energy-efficient technologies described earlier experienced further evolution during this period. Several new technologies emerged.

### **Water conservation**

Numerous products were developed to reduce the use of water in the home. Low-flow shower heads and faucet aerators cut water usage by almost half, while low-flush toilets were able to reduce usage by up to three quarters. Dishwashers and clothes washers were designed to use less water. Low-maintenance landscaping reduced outdoor usage and high-tech versions of old-fashioned rain barrels became popular.

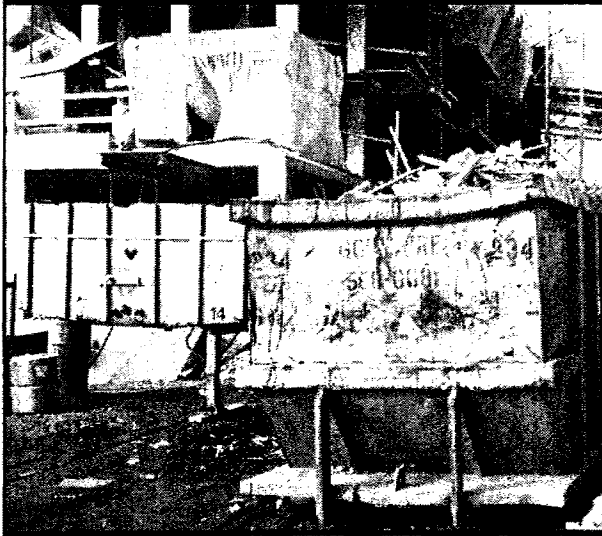
### **CFC-free cooling and insulations**

The disturbing discovery of holes in the ozone layer in the late 1980s accelerated the move away from chlorofluorocarbons (CFCs). This led to the development of alternate refrigerants for air conditioning systems, heat pumps and refrigerators. CFCs had also been used as the blowing agent for foamed plastic insulations. NRC undertook research and testing to assist manufacturers in developing CFC-free polystyrene, polyisocyanurate and polyurethane insulations.

### **Construction waste management**

In response to the growing landfill crisis affecting several urban centres, particularly Metro Toronto, CMHC worked with the CHBA's local home builders' associations through the Residential Construction Waste Management Challenge to develop strategies for reducing the amount of waste generated from construction and demolition, which represented up to 10 per cent of municipal waste [16]. Based on the "4 Rs"—review, reduce, reuse and recycle—construction practices were developed which minimized on-site waste, incorporated waste materials into construction and sorted waste by source to facilitate recycling.

**Photo 59:**  
Construction waste and its management took on new importance as landfill sites filled up



Existing products already using waste materials, such as cellulose insulation and composite wood panels, revised their marketing strategies to emphasize their environmental advantages.

### **Materials with low embodied energy**

Embodied energy—the energy associated with the extraction, manufacture, transport and installation of building materials—was unknown until the late 1980s. However, it quickly became the focus of research and debate, particularly at the University of British Columbia, NRCan and CMHC [18], when estimates indicated that embodied energy represented between five and 30 years of operating energy in a typical house. The full impact has yet to emerge, but initial research suggests that Canada's traditional wood frame housing technology is low in embodied energy.

### **Materials with high recycled content**

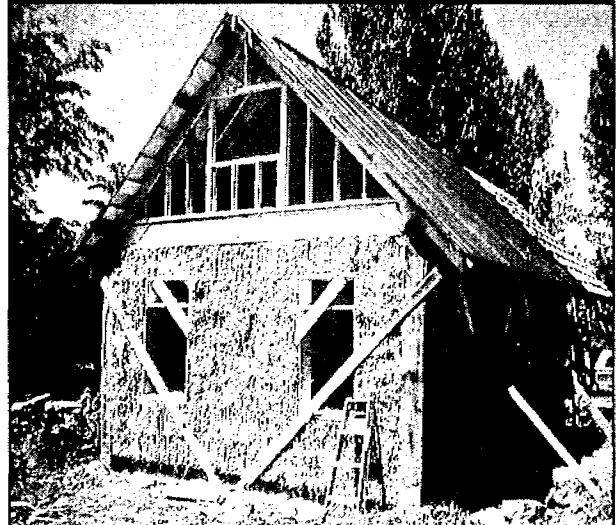
Closely related to the theme of construction waste management was the marketplace explosion of new materials manufactured from waste. Initiatives such as Ortech's Build Green program and Environment Canada's Ecologo labelling assisted in raising consumer and industry awareness. Examples of new applications included:

- carpeting made from recycled pop bottles;
- crushed glass as a substitute for gravel drainage;
- drywall with recycled gypsum and cellulose;
- cementitious roof tiles and siding made from industrial wastes;
- exterior deck framing made from recycled plastic bags;
- recycled mineral wool and glass fibre insulation;
- pavers made from recycled rubber tires; and
- landscaping treatments of chipped wood waste.

**Photo 60:**

The search for sustainable technologies led to a revival of interest in straw bale houses that featured high insulation values and the use of a renewable resource

*Photo courtesy Linda Chapman Architect*



## ***II. SOLVING MOISTURE AND DURABILITY PROBLEMS***

Research on durability, usually involving moisture-related problems, was a dominant theme of this period and was interwoven with the drive for greater energy efficiency.

Construction changes during the post-war period, such as the introduction of plywood and waferboard sheathings, drywall and sealed double-glazed windows, had gradually reduced the rate of uncontrolled air change in new Canadian housing. This did not incur any significant amount of moisture problems, except for the perennial fogging or frosting of windows in winter and the buildup of frost in the attics of northern housing. Wood frame construction was still a “forgiving” system, adequately shedding exterior rain and snow, while allowing internally generated moisture to escape.

The spread of flueless electric heating in the 1960s reduced air change rates further, raising interior humidity levels and causing a greater number of electrically heated houses to experience moisture problems, particularly units with flat roofs or cathedral ceilings.

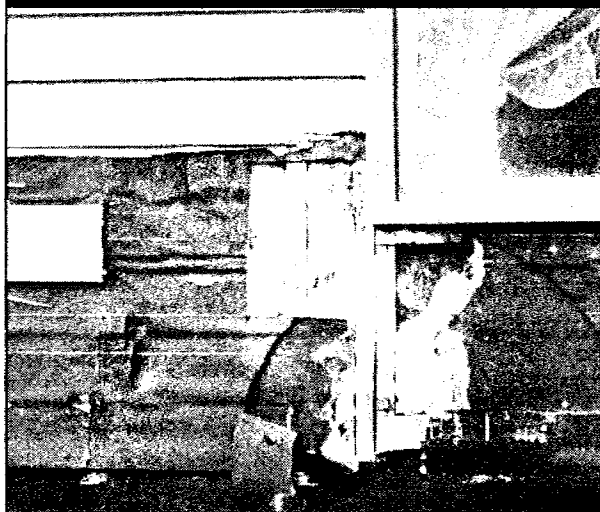
By the early 1970s, the NRC’s moisture research had identified the building science principles underlying moisture control: air barriers, rainscreen construction, the elimination of air spaces around wall insulation, avoidance of low-permeance sheathings, vented attic and crawl spaces, and mechanical ventilation [1]. Such concepts, however, were largely unknown to builders, designers and energy conservation enthusiasts, thus setting the scene for problems in the years immediately ahead. In particular, air leakage—and not vapour diffusion—had been identified by the NRC as early as 1959 as the major cause of condensation problems, but this was not to be reflected in building codes and mainstream practices for another two decades.

### **Condensation in Walls and Attics**

This insufficient appreciation of building science, combined with the rapid changes in construction practices which took place in the aftermath of the energy crisis in the mid-1970s, pushed a number of Canadian houses beyond their limits. Higher-efficiency heating systems, greater insulation levels, more attention to airtightness (although still leaving major routes for air leakage into walls and attics) and night set-back thermostats all contributed to reduced air change rates, lower surface temperatures and a lower neutral pressure plane. This led to condensation problems in attics and upper walls and on interior surfaces at thermal bridges. Concerns over the health effects of mold growth surfaced later. (See Chapter 12)

**Photo 61:**

**Structural deterioration, particularly in the damp coastal regions, resulted in a focus on condensation and moisture problems**



Initial field studies undertaken by CMHC in the late 1970s and early '80s in Atlantic Canada confirmed a high incidence of moisture-related wall problems, particularly siding deterioration. A 1982 national telephone survey and a subsequent

field survey of over 200 moisture-troubled units across Canada were conducted to quantify the problems and identify causes [2]. Problems were concentrated largely in damp climates, such as the Atlantic provinces and coastal British Columbia. A meeting of industry representatives and technical experts was convened to propose solutions and review possible policies [3].

Considerable research and demonstration activities were undertaken in the following years by CMHC, the NRC, EMR and other agencies, in cooperation with the industry [4]. Some of the most significant activities follow.

CMHC began requiring the use of furring strips in NHA-financed housing in Newfoundland, but when the Corporation extended this requirement throughout the Maritimes, the industry protested. This led to the creation of the CMHC/CHBA Atlantic Moisture Task Force in 1985. Test huts were built in Fredericton, Halifax and St. John's to test the drying characteristics of various types of wall construction. Field surveys were also undertaken. The results were inconclusive with regard to the effectiveness of furring, but much was learned about the impacts of wet framing

lumber, sheathing permeability and poor exterior detailing [5]. The moisture test hut program was extended to Ontario and the Prairies in the late 1980s, but resulted in fewer revelations due to more favourable drying climates.

EMR and CHBA incorporated building science principles into R-2000 training and technical requirements, demonstrating to the industry that tight envelopes and mechanical ventilation produced homes that were both energy-efficient and free of moisture problems.

EMR, in support of its energy retrofit programs, undertook a multi-year study in 1985 on how to improve the energy efficiency of Canadian homes without incurring moisture problems. This led to the development of graphic techniques—the Moisture Assessment Prescriptive Procedure or MAPP—for assessing potential moisture problems [6]. Similar methods were developed for determining ventilation needs after airtightening.

CMHC developed the WALLDRY computer model to investigate the drying performance of walls without the expense of endless field tests. The model succeeded in tracking field performance reasonably well and was subsequently expanded into a more comprehensive model, WALLFEM, but moisture mechanisms in exterior walls proved to be very complex. A more fundamental model, TCCC2D, was developed jointly by the NRC and the Technical Research Centre of Finland.

Framing lumber moisture content was surveyed nationally, highlighting the lack of availability of dry lumber in Atlantic Canada.

CMHC applied the principles of rainscreen construction systematically to various types of wood frame walls—vinyl, stucco and brick—to provide advice to builders on reducing rain penetration.

Extensive technology transfer to the housing industry took place through advisory publications written for builders and consumers [7], via training courses (e.g., CMHC/CHBA Builders'

**Photo 62:**  
The Atlantic test huts were used to study different wall assemblies and their drying characteristics to minimize moisture-related problems





Workshop Series, EMR/CHBA's R-2000 courses and EMR/NECA's retrofit installer courses) and at research seminars (e.g., the NRC's 1983 and 1986 Building Insight Series on moisture problems [8] and air barriers).

**Photo 63:**  
The importance of the continuity of vapour barriers, particularly around window and door openings was reinforced through training courses and workshops for builders  
*Photo courtesy Oliver Drerup*



CMHC also undertook research on moisture and ventilation in attics and cathedral ceilings, air barriers (described in more detail in Chapter 10) and internal moisture source strengths in Canadian homes. The NRC explored moisture movement mechanisms in walls and undertook fundamental research on the hygrothermal properties of materials and assemblies.

Forintek Canada Corporation tested the moisture performance of wall assemblies, developed solutions to truss uplift problems and studied the effects of lumber shrinkage on airtightness. The University of Toronto's Centre for Building Science pioneered the development of the dynamic wall concept, in which air is drawn in slowly through exterior walls, recovering heat and eliminating hidden condensation. A dynamic wall demonstration

house was built near Edmonton and evaluated under Alberta's Innovative Housing Grants Program.

More than a decade of intensive research led to a number of key findings. It was determined that moisture problems were primarily associated with flueless heating systems, high indoor relative humidities and damp coastal climates. Reducing excessive indoor humidities was recognized as an important strategy, through controlling moisture sources and providing mechanical ventilation (since passive ventilation is generally too variable to be an effective solution). Damp basements and seasonal moisture storage in building materials were identified as two significant, although less obvious, sources of moisture.

Research confirmed the need for a continuous air barrier to prevent moisture from being deposited in wall cavities and attics. The drying potential of exterior walls in the spring to fall period was found to have a major impact on avoiding long-term moisture problems. This explained why such problems were rare in dry sunny climates such as the Prairies, occasional in temperate climates such as Ontario and Quebec, and more common in damp overcast climates such as the Atlantic provinces and coastal British Columbia. Such drying potential could be reduced by sheathings and claddings with low vapour permeability, while installing furring strips under wood-based claddings could enhance wall drying and reduce the incidence of cladding deterioration. The use of wet framing lumber, with moisture contents in excess of 19 per cent, was identified as a common practice in the Atlantic region, contributing to initial moisture problems.

The proper detailing of flashings and claddings was seen as important in reducing rain penetration. House wraps could also assist in reducing the penetration of moisture from wind-driven exterior sources, while insulating sheathings could reduce condensation in wall cavities and interior surfaces.

**Photo 64:**  
Thermographic images, which indicate temperature differentials, can reveal air loss and condensation in wall assemblies which are not apparent to the naked eye



## Toward Dry Basements

Basements are more common in Canada than in any other country. Originally used as a cellar for storing coal and vegetables, basements gradually evolved in the post-war period into more finished recreational space, with concrete floors, perimeter drain tile, insulation, better windows and “homey” finishes. Throughout their evolution, basements were plagued with summer dampness and mold (as their cool temperatures

were often below the dew point of warm and humid outdoor air), with water leaks in spring and fall, and with inadequate air change.

As homebuyers became more demanding, wet basements became less acceptable. New home warranty programs found that the single most common group of deficiencies related to the basement. In response, the Canadian Portland Cement Association helped develop more rigorous specifications for basement construction, but good concrete alone could not ensure a dry basement, particularly when site building was still very much a matter of “working in the mud”.

A CMHC field study [9] of basement condensation in new homes identified the inevitability of condensation in interior-insulated deep foundations in spring and summer in cold climates. The University of Toronto was instrumental in bringing the advantages of Norwegian-style exterior basement drainage insulation to the attention of home builders. The Ontario Home Builders’ Association led a major study of how to eliminate basement moisture problems [10], highlighting the benefits of air gap membranes. CMHC started from first principles to develop a rationalized approach to basement construction which incorporated an exterior drainage insulation [11].

A CMHC investigation of crawl space moisture control found that current ventilation practices were ineffective. Another study sealed off crawl spaces to alleviate upper floor moisture problems.

Despite an improved understanding of basement moisture problems, construction practices were slow to change, inspiring the NRC to initiate a long-term project in the mid-1990s to improve basement performance.

## Technologies for Improved Moisture Performance in Low-Rise Housing

The following highlights some of the specific technologies, which emerged in response to

concerns over moisture problems. (See the next section on high-rise apartments for additional moisture-related technologies.)

### **Air barriers and air-sealing techniques**

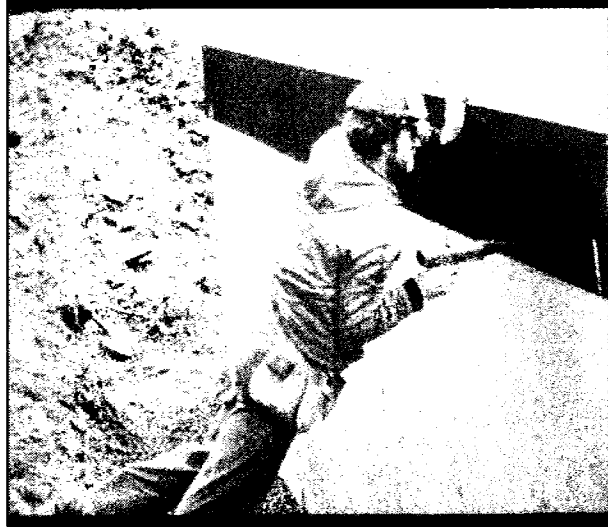
The evolution of air leakage control methods—initially for energy-saving purposes—incorporated sealed polyethylene, the airtight drywall approach (ADA), exterior house wraps and a variety of caulks, sealants and specialty products. It was also recognized as essential in preventing the exfiltration of moist indoor air into wall and attic cavities. Air barrier technologies are described in more detail in the previous section on energy efficiency.

### **Regionally sensitive wall construction**

While few definitive answers emerged as to the “right” way to build exterior walls, it became clear that regional factors, such as climate and the use of wet building materials, called for regionally appropriate construction practices. In damp climates, the use of vented strapping, particularly under wood-based sidings, and vapour-permeable exterior sheathings became more popular to prevent the deterioration of sidings and sheathings.

**Photo 65:**

Exterior basement insulation provided increased energy efficiency as well as directing water to the perimeter drainage system

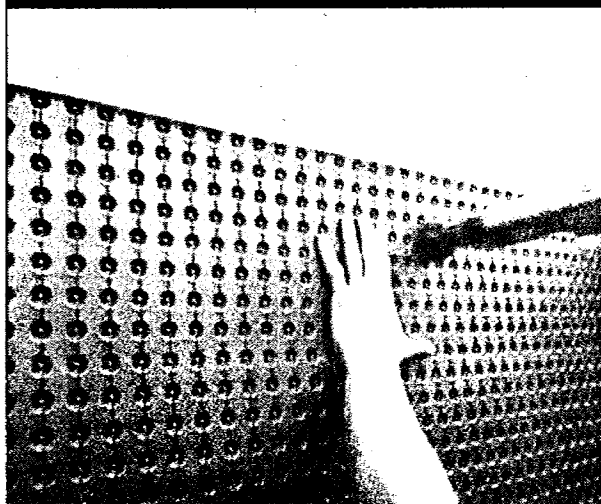


### **Freely draining exterior basement insulation**

The use of exterior insulation grew, primarily as a means of producing permanently dry basements. Placing freely draining glass fibre or mineral wool insulation against the outside of the basement wall, a concept originally developed in Norway (the only other country where people want basements), directed moisture downward to the footings and acted as thermal insulation and soil drain in one.

**Photo 66:**

Dimpled air gap membranes emerged as an effective way to keep basement walls dry  
Photo courtesy Big ‘O’



### **Dampproofing basement floors**

The use of free-draining granular fill and 6 mil polyethylene under basement slabs, isolating the slab from the soil, became commonplace, and a code requirement in many areas. Sealing of the slab perimeter and other penetrations to reduce the entry of vapour-laden soil gas was also introduced.

### **Mechanical ventilation**

From the initial 1977 National Building Code requirement for exhaust fans in houses without fuel-fired heating to the sophisticated performance requirements of the 1991 CSA F326 ventilation standard and the corresponding prescriptive requirements in the 1995 National

Building Code, ventilation systems evolved in capacity, performance and controls, driven initially by the need to control humidity levels. Descriptions of heat recovery ventilators and other ventilation systems are found in the sections on energy efficiency and indoor air quality.

## Building More Durable High-rise Walls

The explosion of high-rise construction in the 1960s created a need for building science advice on durable cladding systems. Because high-rise walls are subjected to much greater stack pressures, wind forces, structural movement and thermal/moisture movement than similar low-rise walls, greater attention to detail and workmanship is required. CMHC assembled the results of the NRC's and its own research to publish the first advisory document on modern high-rise masonry walls, *Exterior Wall Construction in High-Rise Buildings* [12] in 1981. This publication described the application of air leakage control, rainscreen design, flashings, expansion joints and construction tolerances to a variety of wall types.

In the following years, it became evident that there were a number of performance problems with such walls, particularly those using the relatively new system of masonry veneer on steel stud backup. Repair costs were very high, often entailing the removal of large sections of brickwork. CMHC then began a multi-year effort to research the causes of such problems and develop solutions. Efforts focussed on the corrosion of wall ties, the structural stiffness of steel stud backup systems, cavity condensation, rain penetration and movement joints between the steel studs and the structure. This work culminated in a national seminar series on brick veneer walls in 1989 and a completely revised edition in 1991 of *Exterior Wall Construction in High-Rise Buildings*, including specific advice on improving the performance of brick veneer on steel stud backup walls [13].

**Photo 67:**  
Corroded studs and dislodged bricks pointed to problems in high-rise construction techniques



In parallel, CMHC undertook considerable work with the NRC and private consultants and laboratories on air barriers for high-rise walls, protocols for measuring air leakage and air flow patterns in high-rise buildings, and commissioning and monitoring methods.

CMHC initiated studies of the new exterior insulation and finish systems (EIFS), identifying problems and improved detailing practices.

Despite ongoing improvements, multi-family buildings continued to be a major concern for warranty programs due to the high costs of repairs, prompting CMHC and the Ontario New Home Warranty Program to develop a special construction manual and seminar series [14]. To spur innovative solutions in the design of durable building envelopes, CMHC made this a major aspect of the 1994-95 IDEAS Challenge competition.

## Restoring Failed Concrete

In the late 1970s, a durability problem surfaced which threatened the economic viability of many condominiums and apartment buildings—the deterioration of concrete parking garages. Similar to problems being experienced by commercial buildings and bridges, the concrete's reinforcing steel was being corroded by de-icing salts and moisture. The costs of repairs were horrendous, often greater than the original cost of construction. Worse, there was no guarantee such repairs would last and little was known about how to predict such failures.

**Photo 68:**  
Salt and moisture combined to cause widespread failures in the concrete of parking garages



CMHC quickly reacted to this issue, in large part because of the Corporation's position as owner or insurer of a great many multi-storey residential buildings. In 1981, CMHC conducted a survey involving 84 parking structures in the Ottawa area. This was followed by a multi-agency survey of major Canadian cities and a background study to document causes and repair options [15].

The Canadian Institute of Public Real Estate Companies (CIPREC) then initiated a long-term study on repair strategies from 1987 to 1992 with CMHC, the NRC, the Ontario Ministry of Housing and Public Works Canada [16]. The performance of 62 parking garages was monitored over a four-year period and extensive supporting research was undertaken. Non-destructive testing methods were explored. The NRC evaluated sealers and elastomeric waterproofing membranes, finding great variation in performance. CMHC assisted the development of cathodic protection techniques and published a user's guide. Two CSA standards were developed: S413, Durable Parking Structures, for the design of new structures and S448.1, Repair of Reinforced Concrete in Buildings. The results of these research efforts were compiled into a comprehensive manual on cost-effective concrete repair [17] and led to a cross-Canada seminar series in 1994, sponsored by CMHC, the NRC and the Canadian Portland Cement Association.

In addition, CMHC investigated other types of concrete deterioration in the late '80s and '90s. The potential for carbonation, a process by which atmospheric carbon dioxide reacts with concrete, was investigated in balconies and precast panels. Non-destructive methods of assessing corrosion in the tendons of post-tensioned precast concrete structures being developed in the private sector were evaluated in conjunction with the NRC.

## 12. CREATING HEALTHIER INDOOR ENVIRONMENTS

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Indoor environmental technology was very much a product of the post-energy crisis period. In the 1960s and '70s, the Canadian housing industry and public were generally unaware of any health risks in indoor air. Mechanical ventilation was minimal in typical new homes. In contrast, by the mid-1990s, public concern over indoor air quality (IAQ) ran high and an increasing number of homes were being built or retrofitted with low-emission materials and sophisticated ventilation systems.

### Public Concern over Indoor Pollutants

What caused this transformation in attitudes and technologies? Three related concerns which emerged in the late '70s and early '80s—urea formaldehyde foam insulation, moisture and mold problems, and combustion spillage—caught the public's and industry's attention and effectively initiated a new era in building science research in Canada.

#### The UFFI controversy

The single most politically charged factor—and the one which captured the media's interest—was the federal government's decision, in 1980, to ban the use of urea formaldehyde foam insulation (UFFI), due to the suspected health effects associated with the release of formaldehyde gas. This product had been used extensively in the 1970s, particularly as part of the CHIP program, and was estimated to be in 100,000 Canadian homes. Consumer and Corporate Affairs Canada coordinated a massive program to test and inspect homes and to subsidize the removal or sealing of UFFI. Homeowners became alarmed, attributing all kinds of health ailments to UFFI, and the resale value of their homes dropped. Although subsequent research failed to find any correlation between UFFI and formaldehyde levels or reported health effects, and although the longest civil court case ever held in Canada concluded that there was insufficient basis for claims, the "UFFI crisis" as it came to be called, irreversibly affected public awareness and unfortunately

created a perception that energy-efficient housing was more prone to Indoor Air Quality problems.

In retrospect, UFFI was a scapegoat for a more general problem—the evolution of construction practices and research which failed to consider the complex interactions among the building envelope, the mechanical system, the occupants and the indoor environment.

Many of the housing production changes, which had been introduced in the post-war period to save labour, had also gradually made building envelopes more airtight, reducing air infiltration. The growth of electric heating meant less air was being exhausted up chimney flues. The various energy retrofit programs implemented in the wake of the 1970s energy crisis introduced additional insulation, weather stripping, more efficient furnaces and oil-to-electric conversions, further reducing natural air exchange. Yet, there was little understanding at that time of the need for mechanical ventilation, or of the interactions among house systems. Meanwhile, Canadians were bringing more synthetic materials and chemical products into their homes and generating more moisture.

#### Combustion spillage and mold problems

Some homes developed problems with the spillage of combustion products, especially from naturally-vented furnaces and fireplaces. A national survey released by CMHC in 1984 suggested that a significant percentage of homes could be suffering from periodic combustion spillage [1]. Others houses began to experience moisture-related deterioration, particularly in damp climates, such as Atlantic Canada (as was discussed in the section on durability). By the late 1980s, people began to recognize that such moisture problems affected house durability as well as occupant health. A national survey of 20,000 Canadian homes by Health and Welfare Canada [2]—as well as several international studies—identified links between moisture

problems and children's respiratory disease, with mold suspected as the cause.

**Photo 69:**

**The growth of mold in this wall points to air and moisture leakage around the poorly sealed electrical outlet**

*Photo courtesy Canadian Home Builders' Association*



Several additional issues surfaced later to add further impetus to indoor environment research. In the United States, radon was identified as a major cause of cancer, spawning an entire industry devoted to mitigation measures. High levels of radon were also found in Canadian homes in some areas. Other pollutants were found to be entering homes from the soil, particularly near landfill sites and former industrial areas, raising concern over "toxic lands". Similarly, asbestos (particularly from insulations) and lead (primarily from leaded paints) were identified as indoor environment hazards.

Concern grew not only over formaldehyde, but over the hundreds of other volatile organic compounds (VOCs) emitted into the indoor air. Secondhand tobacco smoke was branded as a health hazard, and as smoking became increasingly banned from workplaces and public buildings, attention shifted to the emissions from building materials, furnishings, office equipment

and consumer products. The media began reporting on complaints of sick building syndrome. Concerns in the workplace led to concerns about homes. Advisory articles in the press provided important information but occasionally sensationalized the issues.

## **Solutions: Source Control and Ventilation**

These concerns led to further building science research at CMHC, the NRC and EMR, and greater awareness on the part of the housing industry and consumers. The result was an improved understanding of the principles of air and moisture flow, combustion venting, ventilation and pollutant source control, and the development of a house-as-a-system approach. Equally important was the transfer of this knowledge to the industry through training programs and advisory publications.

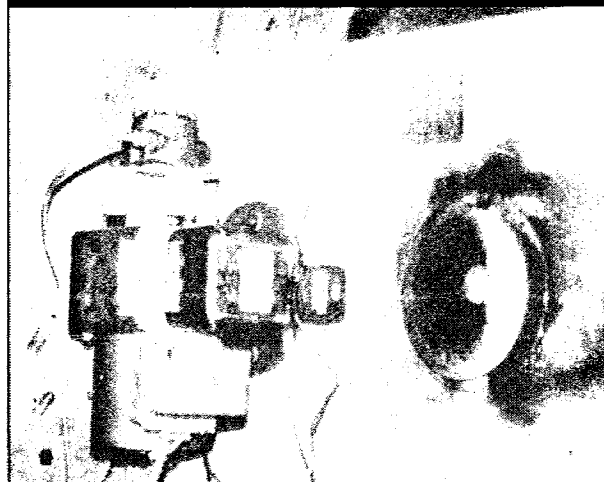
The following highlights some of the significant Canadian developments during this period.

CMHC became an internationally recognized leader in the field of combustion spillage

**Photo 70:**

**One cause of combustion spillage was found to be inadequate combustion air as demonstrated by the backdrafting of this furnace**

*Photo courtesy Canadian Home Builders' Association*



research as a result of field studies, modelling, the development of safety checklists and standards work throughout the 1980s.

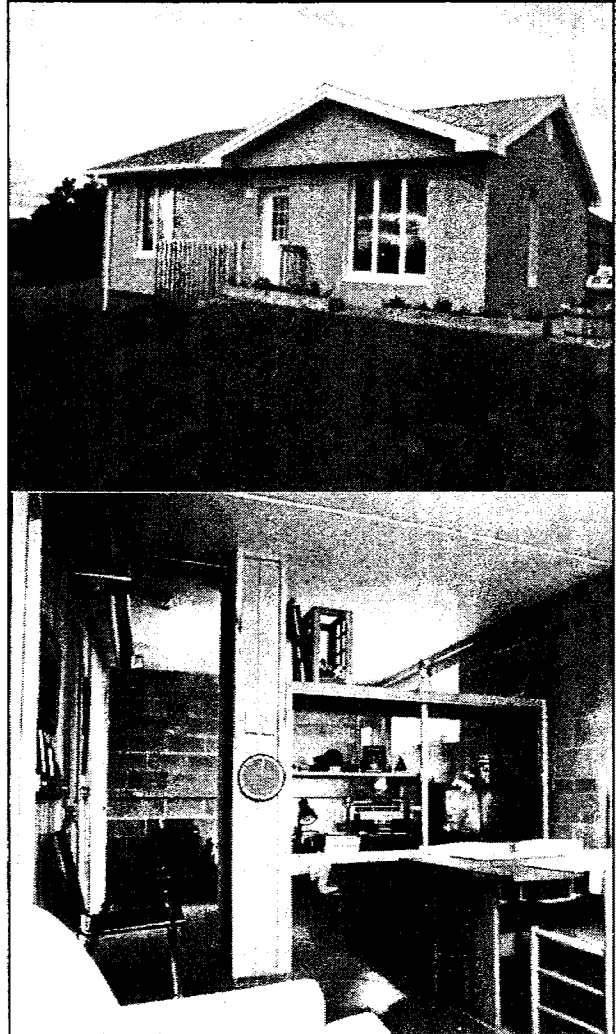
Health and Welfare Canada's *Exposure Guidelines for Residential Indoor Air Quality* [3] were released in 1987, making Canada the first country to have such residential guidelines on acceptable concentrations of indoor pollutants, such as formaldehyde and carbon monoxide. The National Housing Research Committee set up the Working Group on Residential Indoor Air Quality in 1987 to bring together government agencies and industry to identify the most pressing issues. In the '90s, CMHC funded the formation of the Task Force on Material Emissions and the preparation of the *Healthy Materials* newsmagazine to focus efforts on emissions testing and the development of low-emission alternatives.

Ventilation standards were an industry priority throughout the late '80s and early '90s, culminating in the development of the CSA F326, Residential Mechanical Ventilation Systems standard and corresponding changes to building codes.

Canada hosted the triannual international Indoor Air '90 Conference in Toronto which highlighted Canadian IAQ research and also served, along with a public forum organized by CMHC, to capture considerable media coverage, further raising consumer awareness.

CMHC sponsored some of the first studies internationally into the plight of the environmentally hypersensitive. The Residential Rehabilitation Assistance Program was amended to recognize environmental hypersensitivity as a disability eligible for federal assistance to make necessary home modifications. Efforts intensified in the early '90s with funding from the Secretary of State, leading to a demonstration home being built at CMHC's National Office and the publication with CHBA of a guide on material selection [4].

**Photo 71:**  
CMHC's demonstration house for the environmentally hypersensitive used wood-frame construction while a similar project in Barrhaven, Ontario featured concrete floors and block walls



In the early 1990s, in order to detect potential problems from radon or "toxic lands", CMHC adopted a policy of requiring environmental site assessments for mortgage loan insurance on projects of six units or more.

CMHC and NRCan made the indoor environment a major element of their demonstration programs, such as the Healthy Housing Design Competition, the Advanced Houses Program, the R-2000



Program, the Reno-Demo renovation projects and the IDEAS Challenge apartment competition.

The Housing and Health Workshop held in Ottawa in 1995 brought Canadian building and health professionals together on a large scale for the first time to discuss the impact of the indoor environment from both a building science and health perspective.

Starting in the mid-1980s, CMHC produced a series of advisory publications and videos on various aspects of indoor environmental problems for builders, renovators and consumers [5] and developed related training modules for the Builders' Workshop Series, for heating equipment service personnel and for IAQ investigators. In parallel, NRCan entrenched house-as-a-system concepts in R-2000 training and energy retrofit training.

Several key principles emerged from Canadian IAQ research. The importance of source control—both for moisture and pollutants—became clear.

**Photo 72:**

Indoor air quality issues played an important part of CMHC's Reno-Demo projects such as this example in Red Deer, Alberta



Also recognized was the need for ventilation to be controlled and not accidental (i.e., natural), and preferably balanced to avoid pressurizing or depressurizing the house. Combustion systems needed to be sealed or provided with adequate venting and make-up air. The research also confirmed that energy efficiency and good indoor air quality were compatible.

## Clean Air Technologies

By the 1990s, indoor environmental technologies and services emerged as a billion-dollar industry in Canada. The following paragraphs describe specific technologies which emerged as a result of Canadian and international IAQ research.

### Low-emission building materials

Realization of the importance of source control led to increasing demands by builders and consumers for products with lower emissions. Many manufacturers moved quickly to modify their production processes, joining a host of specialty suppliers offering low-toxicity products. The durability of water-borne paints improved, providing an alternative to solvent-borne paints. Zero-VOC paints also became available. Similarly, water-based finishes, stains, adhesives

**Photo 73:**

NRC constructed a stainless steel test chamber to measure emissions from construction materials and finishes  
*Photo courtesy National Research Council*



and sealants entered the marketplace. Carpets with latex-free backings offered reduced emissions. Formaldehyde-free, medium-density fibreboard provided an alternative to particleboard for cabinetry and shelving. Plastic-wrapped insulation batts offered reduced fibre shedding. The development of voluntary emission labelling programs, such as those sponsored by the Canadian Carpet Institute and the Canadian Particleboard Association, and the incorporation of emission requirements into Environment Canada's Environmental Choice Program (EcoLogo) aided the material selection process and led to lower average emissions.

### **Spillage-resistant combustion equipment**

Heating equipment product and installation standards were modified to reduce the possibility of combustion spillage. Sealed-combustion and induced-draft gas furnaces and hot water heaters, along with airtight wood stoves and fireplace inserts, entered the market primarily as energy savers, but their popularity was augmented because of their IAQ benefits. Better chimney designs and stainless steel flue inserts improved venting performance over conventional masonry chimneys. Prototypical sealed-combustion gas ranges and dryers were introduced in demonstration projects.

### **Hazard abatement technologies**

Various radon mitigation techniques and products, including sub-slab ventilation systems, ventilated wall and floor cavity systems, floor drain inserts and wax sealants for cracks and openings, were retrofitted or incorporated into new housing. Similar techniques were adapted to prevent the infiltration of methane and other landfill gases into basements. Chemical and biological treatments to clean contaminated soil were developed. CMHC studied the impact of various leaded dust clean-up techniques in order to provide advice to homeowners and contractors.

### **Ventilation systems and controls**

Initially conceived as an energy-saving technology for airtight housing, heat recovery ventilators underwent considerable refinement and evolution through the 1980s, gaining significant market penetration for the IAQ benefits associated with continuous, balanced ventilation. While noisy, ineffective exhaust fans continued to dominate the market, quiet, well-designed exhaust devices and air exchangers increasingly became available. Various techniques—both passive and active—for introducing make-up air were implemented. CMHC assisted the industry in developing low-cost methods of complying with new ventilation requirements. By the 1990s, the growing popularity and sophistication of home automation systems had created opportunities to adjust ventilation automatically to better meet air quality needs, often relying on carbon dioxide or occupancy sensors. Controlled ventilation systems for individual apartment units also appeared.

### **Filters and air cleaners**

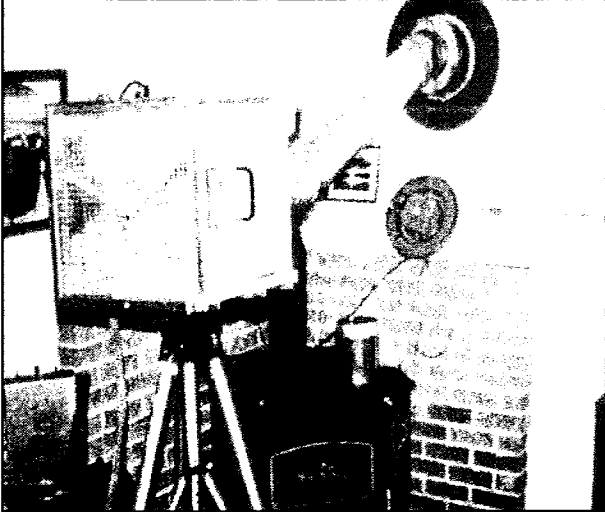
Homeowner concern over indoor pollutants spawned a host of consumer products to remove particulates and gases from the air, including electronic air cleaners, high-efficiency bag filters, medium-efficiency filters and spray-on coatings for standard furnace filters.

### **Testing and monitoring equipment**

Considerable progress in air-sampling methods and instrumentation allowed the detection of lower concentrations of pollutants, time-averaged levels and instantaneous readings. Environmental chamber technology emerged as a means of testing emissions from materials and equipment, with the NRC's room-size chamber being among the most sophisticated in the world in simulating real applications. Methods for testing actual field performance, such as CMHC's duct test rig for assessing ventilation devices, gave troubleshooters powerful investigative tools. Sensor technology became less expensive, resulting in consumer products, such as carbon monoxide detectors and radon samplers.

**Photo 74:**

This testing rig, developed by CMHC, was used to assess the flow, leakage and thermal performance characteristics of ducts and chimneys



## 13. MEETING NEW CHALLENGES AND OPPORTUNITIES

This section summarizes a range of research and technology developments which assisted the industry in addressing new problems and challenges, or which opened up new opportunities to better serve niche markets.

### Independent Living

While much of the research undertaken to improve the suitability of housing for the elderly and those with a disability involved planning and design changes, new technologies also played an important role. The NRC's Division of Building Research spearheaded much of the initial work in the 1970s, culminating in the addition of accessibility requirements to the National Building Code. As the concept of barrier-free design emerged, so did various technical innovations, including automatic door-opening devices, delayed-action door closers, audible elevator controls, more accessible equipment (e.g., drinking fountains, public telephones, kitchen counters, lavatories, toilets, controls), levered door handles and faucets,

special shower stalls equipped with hinged seats, easy-to-grasp handrails and grab bars, and small-scale wheelchair lifts. CMHC's granny flat demonstrations in the 1980s incorporated many of these technologies.

As CMHC gradually took over the lead in this area, the focus shifted from new construction to the adaptation of existing housing. Several publications provided advice on modifications to allow the elderly and those with a disability to maintain independent lifestyles, recommended safety measures to accommodate those with Alzheimer's disease, and catalogued appropriate technologies [1]. The emergence of home automation technologies provided opportunities for integrating communications systems, controls and sensors to provide emergency response systems, improved fire safety and more automated control over lighting and heating [2].

As the definition of disability expanded, CMHC's travelling Open House demonstration in 1992-93 provided Canadians with examples of additional modifications [3]. As well as incorporating many accessible design and equipment features, the demonstration showcased technologies such as an automatic door entry lock, night-activated lighting, a toilet with a personal hygiene device, a roll-in shower, a centralized environmental control system, motorized window controls, a telecommunications device for the deaf, a strobe light smoke alarm and a staircase wheelchair lift, plus low-emission materials and an air purification system.

### Enhancing Safety in the Home

This section highlights technology changes which improved the safety of Canadian homes, particularly in the areas of fire and security.

While most fire-related property damage in Canada occurs in commercial and institutional buildings, more than 80 per cent of fire deaths

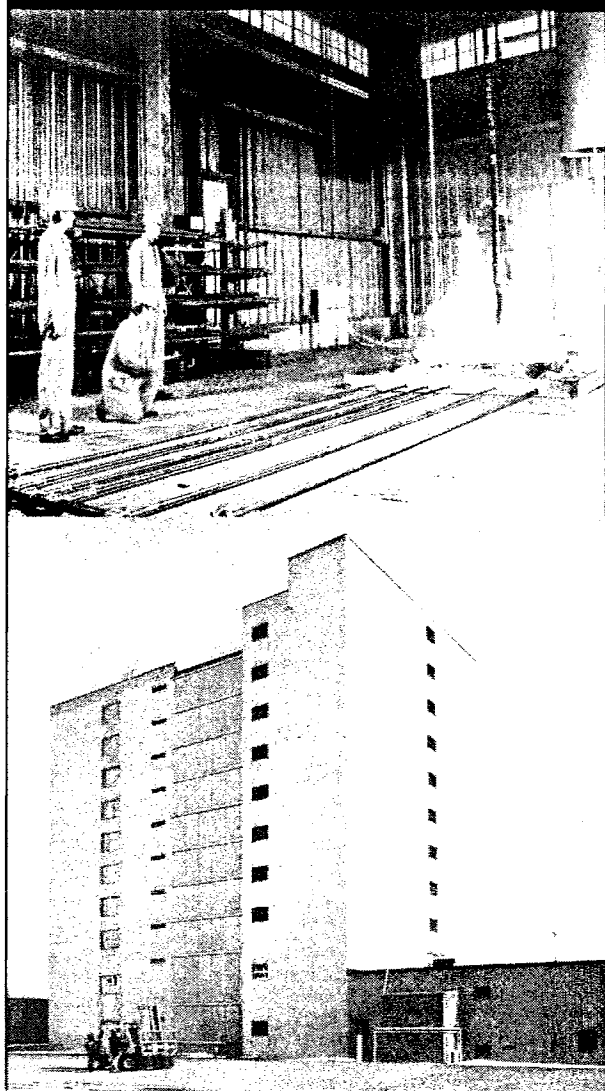
**Photo 75:**  
Manufacturers responded to barrier-free issues by developing new products such as this residential wheelchair lift that could be installed on existing stairs



take place in residential buildings and, therefore, fire safety research remained a priority.

The NRC's Fire Research Section (renamed the National Fire Laboratory in 1989) was the focus of research activities during this period. Test methods were refined and mathematical models developed to better predict the fire resistance of building assemblies. The NRC's full-scale test facilities, which were opened in 1981 and included a large burn hall and a

**Photo 76:**  
Researchers observe a fire experiment at NRC's large laboratory near Almonte, Ontario which includes a 10-storey tower for full-scale research into smoke movement and control  
*Photos courtesy National Research Council*



10-storey tower, proved invaluable in the study of flame and smoke spread, flashover, fire gases, fire resistance of assemblies and fire suppression methods. The results of such research became the basis for revisions to the National Building Code and the National Fire Code.

A major NRC thrust initiated in the mid-1980s involved the multi-year development and validation of the Fire Risk Evaluation and Cost Assessment Model (FiRECAM), in collaboration with Australian researchers, for evaluating the impacts and cost-effectiveness of fire safety options. The absence of such an evaluation tool had made the issue of fire safety equivalencies a thorny one, particularly with regard to the renovation of older buildings. Most jurisdictions were uncomfortable with the liability associated with any deviation from code requirements. CMHC funded a study of alternative measures for ensuring fire safety in existing buildings [4], and later in 1992, sponsored the Forum on Renovation Codes, followed by the development of guidelines on applying National Building Code Part 9 requirements to existing housing.

### **The sprinkler debate**

The single most interesting and controversial issue which arose was the debate over mandatory fire sprinklers. In 1983, the Canadian Association of Fire Chiefs proposed making automatic fire extinguishing systems mandatory for all residences. The cost effectiveness of sprinklers has been an ongoing cause for concern, but the measure has been strongly supported by fire chiefs and the fire sprinkler industry. Municipalities saw potential reductions in their firefighting budgets and some, notably Vancouver, incorporated mandatory sprinklers into their municipal by-laws. The Standing Committee on Fire Protection agreed to consider the issue and, together with the Standing Committee on Housing and Small Buildings, established the Joint Task Group on Mandatory Installation of Sprinklers in Houses to study the implications.

CMHC played a key role in the debate, funding a series of studies into the costs and benefits of sprinklers and other fire safety measures. Such

studies [5] found that the associated cost per life saved was at least \$38 million—one to two orders of magnitude higher than other legislated safety measures. Also emerging from these studies was the effectiveness of smoke alarms and the need to address the causes of fires. The Joint Task Group ultimately recommended against mandatory sprinklers in houses (except for persons with special needs), but recommended that several National Building Code fire safety requirements be relaxed where sprinklers were installed. CMHC subsequently developed a strategic plan for improving residential fire safety, including ways to improve smoke alarm technology to increase reliability.

New products and technologies emerging during this period included fire retardant treatments, materials with improved flame spread and smoke development characteristics, automatic sprinklers and improved fire and smoke detection systems. Various methods were developed for containing the spread of fire and smoke in tall apartment buildings, such as stairwell and vestibule pressurization systems, designated refuge areas, special elevator controls and central communication and alarm panels for firefighters' use.

### **Home security**

While code committees and the housing industry focussed on fire safety requirements, the general public was more concerned with safety from crime. Electronic home security systems, involving motion detectors, pressure sensors, window and door sensors, lighting controls and alarms, became a major business and one of the major drivers behind the growth of home automation systems. CMHC developed a consumer guide to residential security and undertook studies of improving resistance to forced entry, such as evaluations of sliding patio doors and locking devices, and evaluations of wood frame walls and door jamb spreading.

Home do-it-yourself improvements continued to be a significant source of accidents. CMHC developed a guide on avoiding renovation hazards

[6] and encouraged the use of the inexpensive safety equipment increasingly available to the public.

### **Seismic upgrades**

The devastating 1989 earthquake in San Francisco alerted Canadians to their own vulnerability, particularly in geologically active areas such as Vancouver. The NRC's research on seismic upgrades found a receptive audience. CMHC developed publications and videos for builders and homeowners, encouraging upgrades.

### **Designing Quieter Environments**

When complaints of floor springiness became common in the late '60s following changes requested by lumber producers to lumber stiffness/span standards, HUDAC (CHBA) worked with CMHC, the Forest Research Laboratories and lumber manufacturers to address the problem. Floor squeaking and disfigurement of interior finishes were found to be usually caused by excessive shrinkage of drying wood exposing the heads of nails or other fasteners. Suppliers developed new fasteners and adhesives that performed better. The later development of engineered wood composite joists was spurred, in part, by a desire for improved acoustic performance, with one manufacturer marketing its product as "the quiet floor."

Urban population growth and greater traffic densities focussed attention on protecting housing from external noise. The LeBreton Flats demonstration provided a testing ground for the use of sound barriers at grade and on balconies to reduce noise penetration into units.

The emergence of low-rise, medium-density housing and condominium ownership led to increased occupant complaints over noise from adjoining units. Complaints seemed to be particularly acute in Quebec, where noise control was ranked by those attending CMHC's Builders' Workshops as a high priority. In response, CMHC developed the *Noise Control* advisory document [7] in 1987.

During this period, the NRC's Acoustics Section led much of the research on noise control, often in collaboration with CMHC. Considerable progress was made in developing test facilities and measurement techniques, particularly for low-frequency noise, impact noise and flanking noise (noise which bypasses rated wall and floor assemblies). Construction techniques were developed for improving the sound resistance of party walls, suite doors and floor-ceiling assemblies in apartments. Various strategies were demonstrated for controlling plumbing noise in multi-family dwellings through pipe insulations, resilient furrings and pipe attachments, and similarly for reducing appliance noise through resilient pads. Requirements for acoustic separation between dwelling units were made more stringent in the 1990 National Building Code. The 1995 National Building Code included extensive data on the fire and sound performance of a wide range of wall constructions.

New products entered the marketplace, such as quieter exhaust fans, plastic electrical boxes with built-in gaskets for party wall applications, and various kinds of resilient pads and attachments.

### **Overcoming the Environment: Northern and Remote Housing**

The extreme environmental conditions of the Arctic accelerate the deterioration of housing components, magnifying any construction flaws or weaknesses. By the 1960s, it was recognized that transplanting prefabricated southern bungalows was not the solution to northern housing challenges, and an era of research and demonstration was initiated, led initially by the NRC and then by CMHC. So many experiments were undertaken that some northern communities became virtual "museums" of successes and failures—plywood stressed-skin panels, metal and polyurethane "freezer panels", log systems, Quonset huts with arched roof/walls, "super-insulated" houses—leading to the common complaint by northerners that repair and maintenance were difficult due to the lack of replacement components. However, by the

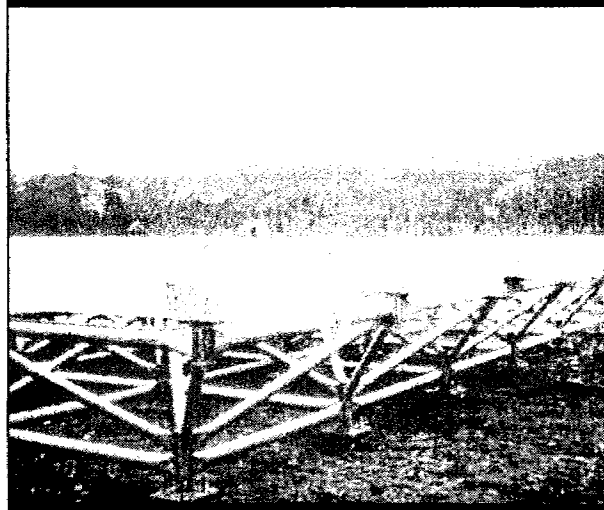
1980s, enough had been learned that a consistent philosophy was emerging [8], particularly in the housing sponsored by CMHC and the housing corporations of the Northwest Territories and Yukon.

#### **Innovative foundations**

Stable foundations were recognized as the key element. Permafrost and other unstable soil conditions caused racking which disturbed the integrity of the building envelope. The most common approach was a pads-and-wedges system or "mud floats", which consisted of levelling shims on a spreader beam on layers of pressure-treated timbers on a gravel pad. Rock-filled wood cribs provided a more permanent solution. Better still, but more expensive, were drilled piles, either of steel or pressure-treated lumber. "Greenlandic" foundations, consisting of cross-braced wood posts frozen into permafrost with a layer of insulation to protect the permafrost, were also used.

CMHC undertook various investigations of improved foundation technology. Strategies for retrofitting existing foundations with simple hand tools were developed. The feasibility of three-point foundations was studied as a solution

**Photo 77:**  
Space frame foundations were used successfully in the North to counteract differential settlement on permafrost



to racking problems. This eventually led to the successful demonstration—both in new and retrofit situations—of a space frame foundation system. Initial versions rested on just three points, while later versions had a multi-point approach using small bearing points to crush the soil and redistribute uneven loads. Another unique approach was the “monocoque house”, demonstrated in Vancouver with the Council of Forest Industries and in Whitehorse with Yukon College and the CHBA’s Yukon Home Builders’ Association. The exterior walls, floor and roof

were rigidly connected with sheet metal plates to form a structural shell or monocoque resting on four bearing pads and designed to withstand differential movement of the foundation.

### Envelope technology

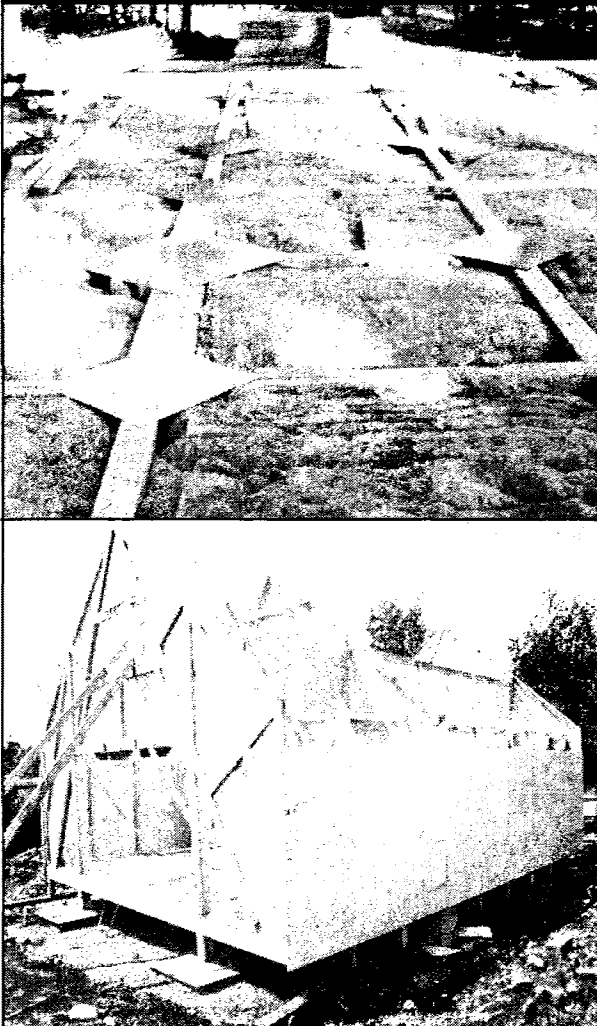
Considerable evolution took place in building envelope design and construction. Prefab panellized systems, which traditionally suffered from excessive air leakage after racking movements opened up their joints, were improved through the use of tongued joints, cam locks and gasketing systems. These became less common with the decline in building new mining towns in the North. Various combination systems of wood framing, rigid insulation, trusses and sprayed polyurethane were also developed to achieve higher insulation levels than commonly obtained with conventional framing. Greater care was focussed on air and vapour barriers, since small imperfections quickly led to more severe moisture problems than in milder climates. The use of an exterior wind barrier also became common.

Many other special considerations affected envelope technology. Various strategies were developed to anchor the house against strong wind uplift, such as “deadman” tie-down bolts. Elevated designs without any solid skirting were used to prevent heat from reaching the permafrost and also to promote wind scouring to remove snow drifts. Unventilated, insulated attics, which prevented the entry of wind-blown snow and the accumulation of frost from escaping moisture, were used successfully in both new and retrofit applications. To avoid the perennial problem of cold floors, especially with open crawl spaces, warm air plenums were often built over the floor structure and measures were taken to better seal the underside of floors against windwashing.

Exterior doors were regarded as particularly problematic, spurring research on air-lock entries, methods of avoiding warpage and ice buildup, and more durable weather stripping. Windows posed similar problems, including excessive winter heat loss and summer solar gain, frost buildup, infiltration of wind-driven snow and hardware failure. Many years before “super windows”

**Photo 78:**

The “Monocoque house” used sheet metal plates to connect the structural elements and form a rigid shell to counteract permafrost settlement. This allowed the house to rest on only four bearing pads





became popular in the south, triple- and quad-glazed units were installed in northern housing. PVC frames became common.

### **Mechanical systems**

Heating systems continued to rely on oil as the primary fuel source. Due to the high costs of electricity for hot water, efforts were made to use oil for combination systems. Oil-fired boilers with glycol/water heating convectors proved to be complicated to maintain. Adding a fan coil and hot water storage tank to provide forced air heating from an oil boiler was a promising advancement. More efficient airtight wood stoves also became very popular where wood was available.

Alternate methods were explored for providing ventilation. Heat-recovery ventilators were adapted for -40°C conditions, although most experienced difficulties below -20°C. Exhaust ducts were run downward through floors to prevent the passive losses and frost accumulation associated with conventional systems which exhausted through ceilings and attics. Baffled vent boxes were often installed above or below windows to provide ventilation in winter without having to open windows.

Above-ground “utilidor” systems lost favour due to their costs and were gradually superseded by below-grade insulated services, often heat traced. Water storage and sewage holding tanks remained common, but were improved through the use of glass fibre or polyethylene tanks with “quick-connect” exterior couplings for filling or pumping.

In 1987, CMHC and EMR established a joint venture with the industry and territorial housing agencies to provide ongoing technical assistance for improvement to northern housing quality and affordability through the creation of the NORTH (Northern and Remote Technology in Housing) Committee. Initial priorities were improved oil-fired heating systems, low-temperature HRVs, passive ventilation systems and suitable door and window hardware.

### **Applications in remote housing**

Many of the results of Arctic research were also applied in rural and Native housing in the northern provinces where the climate was somewhat less harsh, but remoteness and lifestyle posed similar challenges. Particular attention was paid to foundations, durable interior and exterior finishes, simplified heating and ventilating systems and solutions to moisture problems.

CMHC’s “Crofter” unit, which was demonstrated in the 1980s in various forms in several locations, attempted to pull together many of the lessons learned. Innovations included a heated sub-floor plenum, coils for preheating hot water with a wood stove, a mechanical closet for mixing and preheating ventilation air, a one-piece metal flue capable of withstanding the creosote fires often associated with wood burning, rigid insulation on the inside of exterior walls for condensation control and a concrete pier foundation with steel joist floor support [9].

The RNH Demonstration Program, which built about 500 units throughout northern Canada from 1986 to 1991, sought ways to reduce costs through self-help construction and simpler technologies [10]. Various alternatives

**Photo 79:**

**The RNH Demonstration Program sought ways to reduce northern housing costs through self-help construction and simpler technologies. This example is in Davis Inlet, Labrador**



were demonstrated, especially in the initial years, including prefabricated systems, logs, straw bales, monocoque construction modules and minimum-volume packaged kits. Ultimately, basic site-built wood frame construction proved the most economical for most areas, leading to the development of pre-cut material packages and detailed instruction manuals.

Beyond purely technical considerations, northern housing research during this period also focussed on developing technologies which were culturally appropriate, facilitated self-help construction, and allowed for ease of repair and maintenance. (The logistical challenges of Arctic housing are discussed briefly in Chapter 8.)

### **Avoiding a Crisis in Infrastructure**

The rising costs of extending municipal infrastructure, combined with an increasing need for existing systems to be repaired, led to a shortage of serviced land in the 1980s and contributed to escalating house prices in some urban centres. In 1988, the Federation of Canadian Municipalities estimated that upgrading urban infrastructure would cost \$12 billion to \$15 billion, and by 1991, the Canadian Home Builders' Association had elevated infrastructure to the industry's top priority. In 1992, CMHC and the CHBA co-sponsored the Infrastructure and Housing: Challenges and Opportunities conference [11] to focus attention on the issues.

CMHC had recognized the need for alternate approaches to handling water and wastewater as early as the 1950s and undertook research which led to the development of CANWEL—the Canadian Water Energy Loop—in 1971. CANWEL's history is documented in detail in *Two Decades of Innovation in Housing Technology: 1945-1965*. In summary, CANWEL was an integrated waste management system which recovered domestic water from waste water and recovered energy from refuse, at a cost estimated to be less than conventional services. The Liquid Waste Treatment Subsystem used biological, physical and chemical processes to produce

water suitable for undiluted discharge. The Water Polishing Subsystem upgraded the discharge for potable uses. A third component, the Solid Waste Treatment Subsystem, incinerated refuse and solids from waste water to heat water. Although CANWEL was demonstrated successfully in Toronto and Vaudreuil, it was an idea which was ahead of its time and attracted little support from municipalities. Financial constraints caused the project to be shut down in 1978. The initiative was reactivated in 1981 with an evaluation of installed systems [12], but no further research or demonstrations were undertaken.

Septic bed treatment of waste water in rural and unserviced areas—initially identified as an issue in the immediate post-war building boom—continued to create problems both for homeowners and the environment. By the early 1990s, septic systems had surpassed even foundations as the major low-rise housing problem area for warranty programs. CMHC funded the development and demonstration of improved septic systems, such as anaerobic filters for septic tank effluent treatment and contour trench systems. Shallow low-pressure sewer systems were also demonstrated for servicing small communities on rocky terrain. Systems which pre-treated sewage led to improved performance of septic systems, especially in areas where gravel was not readily available. Biological toilet technology improved, becoming more popular in areas not serviced by municipal systems.

Another infrastructure challenge was storm water management. Various studies found that municipal stormwater strategies were a major cause of basement flooding from storm, sanitary and combined sewers [13]. Research was undertaken on backwater valve sump pumps for basements and inlet controls for municipal drainage systems, but the problem remained largely unresolved.

Various technologies emerged during this period to make infrastructure renewal and expansion more economical [14.] One key area was trenchless pipe laying or repairing, using

techniques such as micro-tunnelling with steerable tunnelling machines, directional boring with steerable drilling heads, guided pipe augering, inverted flexible pipe lining and sliplining. New waste water treatment technologies, such as membrane filtration and biological nutrient removal, were developed. The use of underground aquifers for storing treated water was studied as an alternative to large storage tanks and reservoirs. Computer-aided design and modelling gave municipalities the ability to analyze more accurately their infrastructure needs and expected performance.

The emergence of environmental sustainability, combined with water shortages in some areas, led to interest in water conservation and in more “autonomous” housing as a way of stretching the capacity of existing infrastructure. These technologies are discussed in Chapter 10. Prototype greywater recycling and dual pipe systems were developed for toilet flushing, clothes washing and irrigation, reducing potable water use by 30 to 40 per cent. Innovative filtration and purification systems allowed CMHC's Healthy House demonstration in Toronto to rely only on rain and snow for its water supply.

## Responding to Regional Concerns

Innovation took place on many fronts, often in response to a problem or need identified by the housing industry. The following provides some examples of the scope of research and changes.

### Foundations for problem soils

Problem soils, particularly expansive clays, continued to pose challenges. In the mid-1970s, the Mark IX project in Regina tested steel pile foundations and grade beams as a solution. A CHBA-sponsored project showed the effectiveness of gravel drainage pads under foundations. Various engineered solutions were studied for shifting foundations in Winnipeg in the early 1980s. One interesting approach, successfully demonstrated with CMHC assistance in Regina in 1987, consisted of a poured foundation supported on bored piles, a suspended wood floor, no perimeter drain tile and a

sand-bentonite backfill to reduce soil pressures and water penetration. Preserved wood foundations (PWFs or permanent wood foundations, as they were gradually becoming called), became increasingly popular where ready-mix concrete was not available, assisted by the refinement of techniques to protect PWFs from soil pressures and moisture.

**Photo 80:**

**Permanent wood foundations increased in popularity, particularly in locations where concrete was not readily available.**

*Photo courtesy Canadian Wood Council*



### Drywall discolouration

A problem which perplexed home builders in the late 1980s, particularly in Western Canada, involved the discolouration of drywall at joints within a short time after the completion of construction. After considerable research by the NRC and CMHC, the cause was finally determined—a chemical reaction between mercury in the fungicides in the joint compounds and hydrogen sulphide in the air, in the presence of ultraviolet radiation and humidity [15]. Builders were given advice on removing the stains and avoiding the problem through adequate drying time.

### Lumber shortages

Throughout this period, Canadian low-rise housing continued to be dominated by wood

frame construction. However, fluctuating wood prices and concerns over the long-term availability of framing lumber led the industry to explore alternatives. The rapid escalation of wood prices in 1993, as a result of a partial environmental ban on logging in the northwest United States, accelerated this search and CMHC funded a study of alternatives. Lightweight metal framing systems grew in popularity, providing builders with a much more dimensionally stable product than lumber, although thermal bridging problems could not be ignored. Royal Plastics in Toronto successfully pioneered the development of an all-plastic home. Composite wood floor trusses gradually replaced large dimensional lumber in many parts of Canada.

### **Truss uplift**

The Mark XII project in the late 1970s focussed on solutions to this problem. During the following decade, Forintek and CMHC tested alternate nailing and attachment methods which allowed drywall to “float” at wall/ceiling corners, accommodating the upward bowing of roof trusses in winter.

### **Termite protection**

Concern over the advance of the eastern subterranean termite into certain areas in southern Canada in the 1980s prompted research on control methods. CMHC worked with the University of Toronto’s Faculty of Forestry on a multi-year effort to develop low-toxicity wood preservatives, termiticides and biological control agents.

## **14. UPGRADING THE OLD TO PERFORM LIKE THE NEW**

The renovation boom created an entirely new set of demands for innovation. Housing stock managers, renovators and homeowners struggled to bring older dwellings up to current standards of performance, safety and comfort, while trying to preserve their existing character.

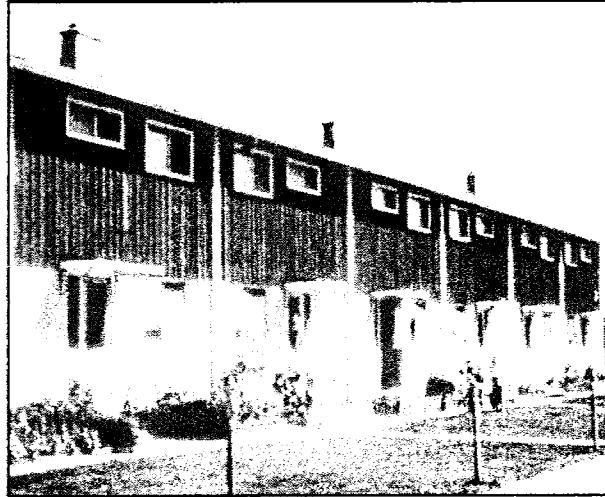
As noted in Chapter 9, the renovation industry's high degree of fragmentation has been a barrier to systematic innovation. However, two themes contributed to considerable innovation in upgrading the performance of older houses during this period: first, the government- and utility-sponsored energy retrofit programs and second, the move to lower maintenance finishes.

Throughout this period, CMHC's priority was on the rehabilitation and preservation of the housing stock. Supporting research, starting in the early 1970s, included numerous studies on the condition of the stock, estimates of repair needs, profiles of the renovation industry and a national consultation. The Residential Rehabilitation Assistance Program, initiated in the early '70s, spawned the first systematic attempts, through the Rehabilitation Skills Training Centre, to train inspectors and installers in applying building science principles when energy retrofitting [1]. This was followed in the 1990s by the National Renovator Training Program, launched in partnership with the CHBA.

Projects, such as Regina's Regent Court rehabilitation in the early '80s, demonstrated the potential for massive upgrading of the public housing stock. A 1985 study demonstrated how to create high-quality basement accommodation in older houses, involving extensive retrofits to ensure a warm, dry suite while protecting the longevity of rubble masonry foundation walls [2]. Several consumer publications [3] assisted homeowners in identifying renovation needs and implementing repairs and upgrades.

**Photo 81:**

**The renovation of Regent Court in Regina, Saskatchewan demonstrated the potential for large scale upgrading of the public housing stock**



Meanwhile, EMR focussed its research efforts on developing energy retrofit techniques which were incorporated into industry publications [4] and extensive National Energy Conservation Association (NECA) training courses for retrofit contractors. In the 1990s, NRCan led the development of HOT-2000 computer-based audit software and guidelines for home energy rating systems, and collaborated with CMHC on the creation of a detailed database on the existing stock. NRC's Canadian Codes Centre and CMHC worked on overcoming regulatory obstacles to renovation. CMHC initiated the first steps toward developing a housing renovation code with a 1995 study of how code requirements could be applied to existing housing [5].

In the mid-1990s, CMHC and NRCan jointly sponsored a series of Reno-Demos—projects with the CHBA's local home builder associations to demonstrate comprehensive approaches to energy retrofits, indoor environment improvements and

functional upgrades. The first project, which was completed in Red Deer in 1994, succeeded in upgrading a 1905 home to near-R-2000 levels of performance.

## Improving the Energy Performance of the Existing Stock

The many incentive programs launched in the wake of the energy crisis, plus the wealth of supporting research and training undertaken by EMR, CMHC, the NRC and the CHBA, led to the development of many energy retrofit technologies. These were refined during the second round of retrofit programs initiated in the late '80s and early '90s by the electrical utilities as part of their demand management strategies.

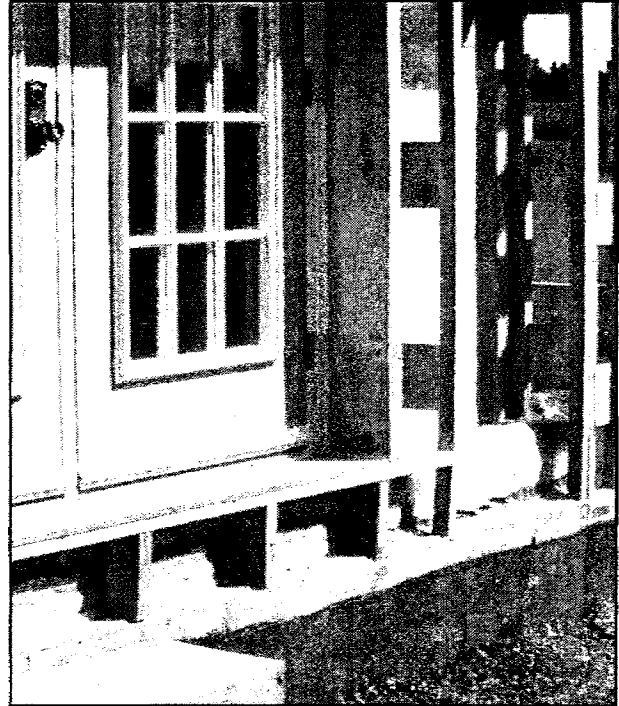
### A systems approach

A key development which emerged—although only after initial problems with moisture, indoor air quality and combustion spillage occurred—was the concept of the house-as-a-system. The initial wave of energy conservation advice in the 1970s was superseded by a second wave of training materials and consumer publications in the '80s which stressed the need to consider interactions among all house systems, particularly the impact of energy retrofitting and airtightening on ventilation needs, combustion venting and moisture.

### Re-insulating

Sprayed foam insulations, particularly polyurethanes and urea formaldehyde foam (later banned in 1980 due to air quality concerns, see Chapter 12) allowed wall cavities in older houses to be filled. Some insulations, particularly polyurethane and dense-pack cellulose, also served to increase airtightness. Re-siding was often accompanied by the installation of exterior insulation and house wraps. Some “super-retrofits” incorporated stand-off wall trusses, such as the Larsen truss of non-structural 2 x 2 in. (38 x 38 mm) on the exterior or a second wall on the interior to accommodate much greater increases in insulation levels.

**Photo 82:**  
Some retrofits incorporated stand-off walls, such as this Larsen truss, to allow for greater increases in insulation levels  
*Photo courtesy Oliver Drerup*



### Low-rise air leakage control

Substantially increasing the airtightness of older homes proved to be a much more challenging task than in new homes due to the near impossibility of installing a continuous barrier to air movement. Comprehensive approaches were developed which involved blocking major penetrations through the ceiling and exterior walls, caulking and gasketing great lengths of indirect leakage paths, and weatherstripping windows and doors. CMHC undertook field trials of comprehensive airtightening in older houses using polymeric emulsions and polyurethane foam. EMR's *Air Sealing Homes for Energy Conservation* provided one of the first comprehensive manuals [6]. Many specialty products were introduced to the market for this purpose, and a blower door test was developed to measure improvements.

**Photo 83:**

Blower door fans were developed to pressurize or depressurize houses to test air leakage levels and aid in thermographic analysis



### **High-rise air leakage control**

Air sealing was later found to be highly cost-effective in multi-family housing. In addition to the techniques used in low-rise dwellings, particular attention had to be paid to sealing party walls in row housing and vertical leakage paths in apartment buildings. Ontario Hydro and CMHC developed air leakage control design procedures and guidelines which were used in Ontario Hydro's extensive retrofit of over 20,000 units in the early '90s [7].

### **Heating system upgrades**

Forced air oil furnaces and oil boilers were converted to natural gas and electric systems in the initial off-oil rush. This also required upgrading and lining of existing chimneys. Subsequent research by EMR's CANMET labs developed several techniques for increasing the efficiency of existing equipment, with the most successful example being a flame retention head burner for retrofitting oil furnaces. Traditional open fireplaces were upgraded with airtight inserts. While most activities focussed on low-rise housing, CMHC also recognized the importance of upgrading central mechanical systems in mid- and high-rise buildings,

demonstrating no-cost or low-cost measures in 30 buildings across Canada and developing an energy-efficient operation and maintenance handbook for multi-unit buildings, where ongoing problems with heating system operation often reduced or negated the benefits of upgrades.

### **Window replacement**

The great volume of windows replaced annually, due to deterioration or aesthetic reasons, provided a major opportunity for upgraded thermal performance and, in fact, the penetration of advanced windows in the retrofit market exceeded that of the new home market. Replacement techniques were also developed for reusing existing wood frames and sashes to maintain a traditional appearance.

### **Low-Maintenance Aesthetics**

Most renovation work was undertaken not for energy purposes, but simply to reduce ongoing maintenance, improve functionality and enhance a home's appearance and resale value.

Kitchen and bathroom renovations were the most popular, spawning a new industry specializing in cabinet refacing. Original wood sidings, stucco and asphalt "brick" largely disappeared, covered in maintenance-free aluminum or steel, and later vinyl sidings. Brick restoration services expanded, moving away from sandblasting, which destroyed the protective outer layer of brick, and toward various water and acid wash techniques to clean brick surfaces. Rekindled interest in historical styles was met by a host of decorative plastic and foam imitations of bargeboards, shutters, window sashes and cupolas.

Foundation repair specialists appeared, armed with a range of epoxy and urethane injections, waterproofing treatments, air gap membranes and underpinning techniques.

New industries and products were developed to enhance outdoor living. Prefabricated sunspaces became common as additions. Pressure-treated lumber enjoyed widespread use in decks, balconies and fencing.

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## ***LIST OF ABBREVIATIONS***

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A-C-T	Affordability and Choice Today: CMHC program
ADA	Airtight Drywall Approach
AHOP	Assisted Home Ownership Program: federal government program
APCHQ	Association provinciale des constructeurs d'habitations du Québec
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CANMET	Canada Centre for Mineral and Energy Technology: part of NRCan
CANWEL	Canadian Water Energy Loop: CMHC research project
CFCs	Chlorofluorocarbons
CGSB	Canadian General Standards Board
CHBA	Canadian Home Builders' Association: which evolved from HUDAC – the Housing and Urban Development Association of Canada formerly NHBA – National House Builders' Association
CHDC	Canadian Housing Design Council
CHIC	Canadian Housing Information Centre: part of CMHC
CHIP	Canadian Home Insulation Program: federal government program
CHOSP	Canadian Home Ownership Stimulation Program: federal government program
CHRP	Canadian Home Renovation Program: federal government program
CIPREC	Canadian Institute of Public Real Estate Companies
CMHC	Canada Mortgage and Housing Corporation formerly Central Mortgage and Housing Corporation
COPs	Coefficient of Performance
COSP	Canadian Oil Substitution Program: federal government program
CSA	Canadian Standards Association
CSCP	Community Services Contribution Program: federal government program
DBR	Division of Building Research: part of NRC, became IRC
EASE	Exterior Air System Element
ECM	Electronically Commutated Motors
EIFS	Exterior Insulation and Finish System
EMR	Energy Mines and Resources Canada, became NRCan
ER	Energy Rating
FiRECAM	Fire Risk Evaluation and Cost Assessment Model
FRP	Fibreglass Reinforced Plastic
GST	Goods and Services Tax
HRV	Heat Recovery Ventilator
HUDAC	Housing and Urban Development Association of Canada, became CHBA
HVAC	Heating, Ventilating and Air Conditioning
IAQ	Indoor Air Quality
IDEAS	Integrated, Durable, Energy-efficient, Affordable Solutions Challenge: CMHC and NRCan competition
IRAP	Industrial Research Assistance Program
IRC	Institute for Research in Construction: part of NRC formerly DBR – Division of Building Research
MAPP	Moisture Assessment Prescriptive Procedure
MURB	Multi-Unit Residential Building
NBC	National Building Code of Canada

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NCC	National Capital Commission
NECA	National Energy Conservation Association
NHA	National Housing Act
NHBA	National House Builders' Association: became HUDAC, became CHBA
NIP	Neighbourhood Improvement Program: CMHC program
NoRTH	Northern and Remote Technology in Housing Committee
NRC	National Research Council of Canada
NRCan	Natural Resources Canada: formerly EMR - Energy Mines and Resources Canada
OPEC	Organization of Petroleum Exporting Countries
PUDs	Planned Urban Developments: planning term
PVC	Polyvinyl chloride
PWF	Permanent (Preserved) Wood Foundations
R-2000	Residential energy efficiency program developed by NRCan and delivered initially by CHBA
RAIC	The Royal Architectural Institute of Canada
RHOSP	Registered Home Ownership Savings Program: federal government program
RNH	Rural and Native Housing Program: federal government program
RRAP	Residential Rehabilitation Assistance Program: federal government program
RRSP	Registered Retirement Savings Plan: federal government program
SEEH	Super Energy-Efficient Houses
SPOTA	Strathcona Property Owners and Tenants Association: Vancouver British Columbia
SRC	Saskatchewan Research Council
UFFI	Urea Formaldehyde Foam Insulation
VOCs	Volatile Organic Compounds

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