RESEARCH REPORT

Opportunities for Accelerating Implementation of Environmentally Sustainable High Performance Housing

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OPPORTUNITIES FOR ACCELERATING IMPLEMENTATION OF ENVIRONMENTALLY SUSTAINABLE HIGH PERFORMANCE HOUSING

By Robert J. Booth
Peter S. Kettenbeil

8 December 1994

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CMHC Project Officer: Jim Robar

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Building Science & Technology

Opportunities for Accelerating Implementation of Environmentally Sustainable High Performance Housing

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Peter S. Kettenbeil

8 December 1994

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Box 73A, Rural Route 1
Dalkeith, Ontario
K0B 1E0, Canada

Tel: (613) 525-2766
Fax: (613) 525-0940

ABSTRACT

Five innovations from recent Canadian housing demonstration programs were selected for their potential to make significant contributions to environmentally sustainable high performance housing. Opportunities for accelerating implementation of these innovations were identified by determining ways to capitalize on opportunities, and ways to overcome obstacles for each innovation. The five innovations were: integrated ground source heat pump systems, integrated high efficiency gas hot water heaters, super windows, water purification systems, and comprehensive landscaping.

Prime motivations for homeowner purchases are cost and comfort; environmental sustainability is secondary for most. There is severe information overload within our industry and yet there is also a need for authoritative information about economic benefits from home improvements. Purchasing decisions are often delayed by confusion about the best approach to be taken for long term benefits.

Effective distribution of simple, clear and authoritative literature on the economic benefits from implementation of various home improvement options is recommended. CMHC documents distributed with utility billing envelopes is an example of cooperative environmental responsibility.

The high purchase price of most energy related environmental products can be overcome with term financing from utilities and product suppliers. As monthly energy usage is reduced, these innovations can literally pay for themselves. Performance warranties from manufacturer associations would reduce performance concerns.

Studies indicate that current standards for potable water do not address all health aspects, most specifically the accumulation of heavy metals. More straightforward communication is required from government at all levels. Acceleration of water purification systems appears to be severely hampered by misinformation.

Landscaping has obvious green appeal. Ways to improve information and responsibility at the municipal government levels are recommended.

Strategies and impediments for innovation in the industry are discussed.

EXECUTIVE SUMMARY

The housing industry is slow to change for many reasons. Most Canadians are reluctant to take great risks with their largest investment and, therefore, changes in housing will occur slowly. "Better mouse traps" are most successful in an industry that accepts innovation in evolutionary rather than revolutionary steps.

The past ten years has seen dramatic changes in the Canadian construction industry. Increased environmental awareness has stimulated numerous innovations that have the capacity to significantly reduce the environmental impact of the "built world". Canadians' concerns for their environment have encouraged new types of cross disciplinary\sectorial collaboration. If this new type of collaboration is properly focused and encouraged, it could profoundly increase the rate of acceptance of environmentally focused innovation within our industry.

This project focused on determining ways to accelerate the acceptance and implementation of environmentally sustainable housing. Necessarily this relates to healthy, durable and energy efficient housing (high performance housing).

The methodology chosen was to review individual innovations from recent demonstration projects; select five innovations; identify opportunities and obstacles regarding their implementation; and identify pathways to overcome obstacles and capitalize on opportunities to accelerate the implementation of these innovations. The innovations chosen are not current innovations in the technical sense, but are innovations with respect to their limited familiarity and acceptance in the marketplace. The intent of this project was to use the selected innovations as vehicles to throw light upon the commercialization process.

Unfortunately recent demonstration projects were not as far advanced as we had anticipated and, although the five innovations were chosen from these demonstration programs, we were unable to obtain sufficiently precise information on cost and performance to undertake financial analyses. This is a weakness in this study, but it was unavoidable.

The five innovations chosen have the potential for major environmental gains and have retrofit potential. They are ground source heat pumps, efficient gas-fired heating systems, energy efficient windows, landscaping, and improved water quality. Their impact upon a single new house is obvious: retrofit increases their potential impact some 65 times.

Leading edge experts in fields of the five innovations were interviewed and up-to-date reliable information was obtained. Opportunities and obstacles were identified, as were ways to accelerate the adoption of the innovations.

Key ways to accelerate this adoption include:

Provision of accurate, reliable and persuasive performance information. Manufacturer association backed performance warranties.

Provision of financing to overcome high initial costs where these costs are offset by reduced energy demand. Cooperative efforts between energy utilities and suppliers will be valuable.

Provision of authoritative third party documentation comparing relative options (products, systems and alternative ways) to accomplish homeowners' goals. This would help prevent confusion and indecision regarding purchases. Agencies such as CMHC would be credible sources of such information.

For rapidly developing technology, manufacturer associations and code and standards organizations could develop computer models that simulate product performance and which would be acceptable to code and standards bodies. CCMC would be a useful resource in this area.

Alliances between innovators and building product distribution groups can significantly reduce market entry costs and accelerate implementation of innovations. There appears to be a role for CMHC & NRCC in establishing such alliances, perhaps through IRAP.

Provision of accurate and authoritative information about water quality is required. This should be simple, clear and short. Government agencies should be credible sources of such information.

Allocation (or withholding) of funds to municipalities for environmental issues is a strong influencer. Provincial governments have a key role here. CMHC could reject financing for houses where municipalities are not environmentally responsible.

Computer-aided territory management techniques such as integration of topographical maps, satellite photography and aerial "videography" (the use of high performance video fly-overs for detailed monitoring) are under used for urban development. A conference on the use of such tools, primarily aimed at local municipal officials, would be useful for technology transfer. Sponsorship by CMHC and Provincial

Housing and/or Environment Ministries would be appropriate.

In a questionnaire to building experts in technical, construction, management and publication positions two messages were clear. First, there is information overload and this is a very serious issue. Second, the influence of government is a major issue.

People involved in commercialization of building products in large and small organizations were interviewed, and literature relating to innovation has been studied. It is clear that the complicated diagrams in many documents have little in common with the initial stage of innovation, which is essentially unstructured. However organograms are required for successful commercialization of innovations as they impose the discipline to consider all factors.

We have discussed the typical path for commercialization of innovations in both large and small organizations. These are different for obvious, but often overlooked, reasons. We have also included a section on regulations and product commercialization, which describes how product acceptance is onerous, but less so than generally perceived. We have presented a flow chart for obtaining product approvals in Canada and the USA. We hope that this will be useful for would-be entrepreneurs.

The house is a system and the innovations studied are subsystems or parts of subsystems. The interaction of innovations is generally obvious and specifically complex. In many documents "synergy" is extensively used to depict positive gains, in fact for many innovations the synergistic effect is negative (energy efficient building enclosures reduce paybacks from energy efficient heating units). This study was undertaken with a holistic view and we have tried to reflect this in the report.

As an industry, we have only recently begun to perceive the inter-relatedness of all techniques and components and how we can fully integrate them to maximize efficiency for individual homes and entire municipal and utility grids. It appears that there is positive synergy and good opportunities for long term environmental and cost savings in infrastructure through conservation measures taken in the home.

We hope that this study will enable participants in all sectors of our industry to better understand the process of innovation as it relates to the environment. We hope that they will have a clearer focus as to how their particular expertise can be applied in a more effective manner to better the environment with better housing.

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1.0 INTRODUCTION

1.1 Background

The homebuilding industry has a long invention-gestation-diffusion rate. An increased acceptance of change within this industry is required for environmental sustainability reasons. Our generation is irresponsible: poor quality water, acid rain can be added to the more visible national debt which we are about to leave to future generations.

Fundamental changes in the way of thinking about houses are required. Fortunately there are signs that our industry has started to develop new vision. The understanding of a house as a collection of interacting sub-systems is beginning to change the way we view house design. Heating, ventilation, air conditioning and domestic hot water systems are integrated to provide maximum efficiency. Integration with appliances is the next obvious step. Energy conservation will result as many appliances work against each other in terms of space heat management. Also there are possibilities for reduced sizing and components.

Health aspects of housing (clean air, water and waste handling) have also caused a radical change in the way we view infrastructure[1]. There is no longer any evidence that bigger is better when it comes to servicing housing. Fundamental changes are required in the way we view infrastructure.

The environmental challenge is changing our perceptions: from specialized disciplines and sectorial viewpoints, to more general and comprehensive viewpoints. This whole-process way of thinking results in the consideration of all aspects of housing, such as waste management, embodied energy criteria, air quality, energy efficiency, cost, water use reduction, attractiveness, comfort, saleability. Some considerations were not in our vocabularies ten years ago: municipal water quality, electro-magnetic pollution, home office considerations.

Just as engineers do more with less by integrating mechanical systems, industry participants have also integrated forces to do more with less. An example of this was the collaboration between manufacturers, distributors, the building industry, municipalities, and utilities to increase the use of energy efficient lighting. The whole-process perspective caused each stakeholder to perceive their common interest and, by pooling resources, they did more with less.

The Healthy and Advanced House demonstration programs required individuals with divergent backgrounds to form "design teams". This

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[1] For the purposes of this report we define infrastructure as site work, landscaping, municipal and utility supplies for housing.

created an environment where individual team members, through the process of addressing all technical requirements for healthy and advanced houses, were obliged to expand their individual horizons to accommodate the whole-process perspective.

The involvement of utilities, municipalities and product manufacturers enhanced the effectiveness of these demonstration programs in facilitating cross-fertilization of ideas. This broader vision by industry stakeholders bodes well for accelerated implementation of environmentally sustainable high performance housing.

This study was proposed with a view to capitalizing on this moment of opportunity to identify the opportunities for accelerating the implementation of innovations demonstrated in these recent demonstration programs.

1.2 Objectives

The primary objective of this study was to identify ways by which recently demonstrated innovations related to environmental sustainability and high performance housing could be accelerated.

Three milestones were:

- To identify five innovations which have potential for a substantial positive environmental impact.
- To identify opportunities and obstacles relating to implementation of these five innovations.
- To identify ways of capitalizing on opportunities and overcoming obstacles, thereby identifying ways to accelerate implementation of these innovations.

1.3 Methodology

This study was initiated with a view to fully assessing recently demonstrated housing innovations in terms of costs, performance and potential for widespread use. The original intent was to assess innovations on competitive fundamentals: performance, costs, technology, marketability.

Unfortunately, information on costs and performance of the innovations selected is not available with sufficient precision to allow us to undertake such assessments and we had to resort to using other sources.

Our revised methodology became:

- The innovations demonstrated in the Healthy and Advanced House demonstrations were used as the starting list for innovations.

- Ten innovations which had potential to positively impact upon the environment were initially selected. Selection was based upon predicted performance, expected costs and relevant supportive literature.
- A questionnaire to industry representatives provided responses which enabled us to select the final five innovations.
- Because of the absence of precise data, the final five innovations selected were "types of innovations" as opposed to the "specific innovations" used in the demonstration houses (eg. we chose integrated Ground Source Heat Pumps/Domestic Hot Water heater/Air Conditioner/Heat Recovery from Ventilator as opposed to any specific system used in a demonstration house.)
- Respondents to the questionnaire provided information on opportunities and obstacles to implementation of innovations, both for the specific innovations and for innovations in general.
- Industry representatives with first-hand experience of innovation in small and large companies were interviewed.
- Key individuals who appear to have leading edge knowledge of relevant industry sectors were interviewed where possible (eg. Cam McNeil regarding heat pump technology).
- A second review of literature was undertaken which specifically targeted the five selected innovations.

Using all of the above information we have identified ways by which each selected innovation type could be accelerated.

We have been unable to provide insight into the innovation process with any precision, simply because we do not sufficiently precise performance and cost information from demonstration programs. We have attempted to give some insight into innovation processes used by larger established companies compared to individuals and smaller start-up companies. We have also provide a typical flow sheet for obtaining building envelope product approvals in Canada and the USA.

2.0 INFORMATION COLLECTION

2.1 Literature

All available literature relating to Healthy House and Advanced House programs was reviewed. This provided an overview of innovations demonstrated and their predicted performance. Literature from other sources which related to performance, potential environmental impact, and acceptance of the demonstrated innovations was reviewed. The Rocky Mountain Institute was contacted, and their latest documentation pertaining to innovations for environmentally sustainable housing was received and reviewed.

A broad spectrum of documentation relating to environmentally sustainable housing in relation to utilities, urban planning issues and successful local initiatives was obtained. There appears to be

major potential for cost effective environmental benefit in the "infrastructure" area. This potential is well documented and demonstrated.

2.2 Questionnaire

A questionnaire (Appendix A) was sent to industry experts. The purpose of the questionnaire was to:

- Help select five innovations from a list of ten.
- Identify opportunities and obstacles for innovation in housing, both in general and with specific reference to the innovations chosen.
- Obtain feedback on R-2000, Healthy House and Advanced House programs.

The results of the questionnaire are discussed in section 5.1.

2.3 Demonstration Houses

The Healthy House and Advanced House programs yielded the following demonstration houses.

HOUSE	TYPE	NUMBER OF STORIES	NUMBER OF BEDROOMS
B.C. Healthy House	Single Detached	2	1
B.C. Advanced House	Infill Single Detached	1½	4
Saskatchewan Advanced House	Single Detached	2	5
Manitoba Advanced House	Single Detached	2	4
Waterloo Region Green Home	Single Detached	1	4
Neat Home - Hamilton	Single Detached	2	3
Innova House - Ottawa	Single Detached	2	3
Maison Novtec - Québec	Single Detached	2½	3
Maison Pérformante - Québec	Single Detached	2	3
Envirohome - Nova Scotia	Single Detached	2	3
Codicile Healthy House - Toronto	Infill Single Detached	2	2
P.E.I. Advanced House	Single Detached	1½	3

2.3.1 Healthy Houses

CMHC launched its Healthy Housing Design Competition in 1991 to demonstrate to the Canadian public and the housing industry that it was possible to design houses for the Canadian climate which were affordable, had healthy indoor environments, and were in keeping with the principles of sustainability. Design teams were invited to submit concepts in three categories: a newly constructed suburban detached home, an older home retrofit, or an urban infill home. The technical requirements established for the competition were organized into five categories, each of which included a range of factors to be addressed:

1. Occupant Health:

    - air quality through reduction of source emissions
    - air quality through ventilation
    - water quality
    - use of lighting
    - reduction of noise and electromagnetic radiation

2. Energy Efficiency

    - embodied energy
    - design heat loss of building envelope
    - energy for heating, cooling and ventilation
    - overall electrical consumption and peak demand

3. Resource Efficiency

    - material selection and use
    - construction waste management
    - water conservation measures
    - durability of house components
    - longevity of house

4. Environmental Responsibility

    - emissions and combustion by-products released by house
    - waste water and sewage handling
    - community and site planning issues
    - minimization and management of hazardous materials

5. Affordability and Economic Viability

    - house affordability
    - viability of design for building industry
    - adaptability of the unit
    - marketability of the unit

The two winning entries, both in the Urban Infill category were, the Vancouver Healthy Housing Project and the Codicile House in Toronto. (18)

2.3.2 Advanced Houses

In 1991, CANMET announced the Advanced Houses competition. Groups from across Canada submitted proposals and ten house designs were selected for construction. Technical requirements included;

- purchased energy consumption targets of 50% that of R-2000 homes and 25% that of conventionally built houses
- integration of water-saving devices and outdoor water use reduction of 50%
- use of low off-gassing building products
- room-by-room ventilation, compliance with indoor air quality guidelines, and thermal and humidity control
- use of Ecologo products, recycled materials and no CFCs
- demonstration of recycling facilities indoors and an outdoor compost bins (11)

2.3.3 Others

U.S. demonstration houses such as the Davis Energy Group's House in Davis California, the Greening of the White House Project, and examples from the Department of Energy's Exemplary Buildings Program were also reviewed for identification of possible complimentary combinations of innovations and further insights into opportunities and obstacles. The Davis House was particularly interesting since by applying an integrated combination of efficiency measures, the need for air conditioning and a furnace were completely eliminated. These energy efficiency measures, many of which are not yet fully commercialized are adding $25,000 to the construction costs of this experimental home. However, based on the projected massively implemented, "mature market costs" of these measures, they would cost about $1,800 more to build than the base case design. Their payback period, using a California criteria for energy costs, is six months. (68)

3.0 SCREENING OF IDEAS

3.1 From Demonstration Houses

With the exception of the Codicile House in Toronto, the demonstration houses have all been constructed. The houses were instrumented in 1993 for performance monitoring.

Unfortunately, as is often the case with such programs, the results from the first winter of operation indicated that there were problems with both the monitoring and installation of some innovations. Because of this, monitoring results from the first winter of operation are somewhat general and suspect. This made it impossible to reliably compare actual versus predicted performance of houses and specific innovations.

The lack of reliable performance information, coupled with the natural lack of cost information for demonstrated innovations both complicated our task and made the results less valuable. We had to rely upon the predicted performance of innovations to select them; and we undertook more interviews and a more extensive literature review to identify ways to accelerate their implementation.

3.2 Initial Screen

A wide "go\no go" screen was established to qualify innovations\prototypes as having potential for a major positive impact upon the environment.

Preliminary interviews were held with innovators, potential users and influencers to identify obstacles and opportunities for successful implementation. We found it difficult to obtain focused feedback in these interviews because of the lack of familiarity of interviewees with the large numbers of innovations used in demonstration houses.

We decided to complete an initial selection of innovations prior to continuing with the interviews.

During this initial selection it became clear that re-thinks and up-grades of known technologies had more potential for superior environmental impact potential than their previous history might suggest. In some cases this was because the original innovations were too narrowly focused, such as heating units with potential for doing double or triple duty if integrated with other functions at the design stage. In other cases, such as water purification and landscaping, the general level of perception of problems and solutions has increased.

Innovations with ongoing environmental advantages such as reduced energy or water consumption, or better waste management, have greater potential than one-time event innovations such as building materials from recycled wastes. However, at this stage of selection, we tried to maintain a broad perspective.

At the start of this project, it was anticipated that an all pairs ranking process would be necessary to select one specific innovation from another. Given the general nature of information available for the innovations, this type of precision was not required. For example, instead of selecting a GSHP/HRV/DHW

configuration over another, we are only able to select this as a general type of innovation.

We understood that it was equally important to identify opportunities and obstacles as it was to select the innovations, because the final step of the project is to recommend ways to capitalize and overcome the opportunities and obstacles for implementation.

Opportunities and obstacles for innovations usually involve:

- Technological Fundamentals: Are they sound? Can they be improved? Is there a better way to accomplish the same thing?
- Commercialization Potential: Is there a payback for the producer? Is there a payback for the user? Is there a high capital or market barrier? Are benefits obvious/marketable? Is there a retrofit market?
- Synergy: Can the innovation be coupled with another to provide more than double value? (eg. HRV+GSHP+DHW+AC+landscaping).

These factors were considered in selecting ten innovations.

Innovation	Principle Reasons for Selection
1. GSHP/HRV/DHW configurations.	Significant non-renewable energy savings, healthy indoor air, multipurpose HVAC/HRV/DHW uses, good retrofit potential.
2. High efficiency gas DHW/heat exchanger/HRV	Significant non-renewable energy savings, healthy indoor air, dual purpose DHW/heating, low cost fuel, good retrofit potential.
3. Contraflow fireplace.	Use of renewable energy source for heating, clean burning, low cost and good retrofit potential in semi-rural areas.
4. Super efficient windows	Significant fuel savings, "free" solar energy source, synergy with HRV and heat pumps for space or DHW heating use.
5. Engineered timber frames.	Increased use of engineered wood products and a complete rethink of timber framing is indicated.
6. Recycled polyester fibrous insulation.	Interesting entrepreneurial project where innovator has "lived" 5 years of experience of opportunities and hurdles regarding implementation of innovation.
7. Water conservation	Good example of resource management where one area impacts on many others for a major short and long term contribution.
8. Water purification	Timely issue, great importance to long term health, excellent potential benefit/cost ratio.
9. Comprehensive landscape	Reduces CO_2 , increased energy efficiency, local air quality, water use reduction
10. Indoor Plants	Reduces indoor air pollutants, low cost solution, quality of life attributes

3.3 Final Screen

The final screening process involved a more thorough version of the initial screen with the added input from questionnaire respondents. Five innovations were selected for a thorough examination of the obstacles and opportunities affecting the acceleration of their implementation.

Energy efficient windows.
GSHP/DHW/HRV systems.
Gas DHW/HE/HRV systems.
Landscaping.
Water purification.

4.0 THE FIVE INNOVATIONS SELECTED

4.1 GSHP\DHW\HRVs

Ground source heat pumps (GSHPs) yield energy efficiencies greater than 1:1. Currently it is possible to obtain over 3 units of energy output for 1 unit of purchased energy input. This makes GSHPs the most efficient and environmentally benign form of heating. Unfortunately GSHPs are expensive to purchase, but when integrated with domestic hot water heaters and heat recovery ventilation units, both capital[2] and operating costs decrease. The low operating costs and high efficiencies come from the use of renewable solar energy stored in the earth (man-made energy is only used to drive fans and pumps).

Well designed and integrated GSHP systems have COPs (coefficients of performance) close to 4. Despite using relatively expensive electricity, this 400% efficiency makes them cost competitive with gas and oil. In addition, GSHPs offer economical air conditioning (a reversing valve allows heat in the house to be routed to the ground, at the same time this waste heat can provide domestic hot water). If sold in volume, component and assembly costs would significantly reduce. Apart from the reversing valve the componentry of a GSHP is identical to a refrigerator.

In homes with large south facing sunspaces, integrated systems of this type will assure proper circulation and use of solar gain throughout the house in winter (solar energy=space heating=HRV exhaust=GSHP ground loop). In summer, sunspace overheating can be controlled, and routed to provide "free" hot water (HRV=GSHP=DHW).

Utilizing earth energy reduces greenhouse gases, particulate, and other emissions associated with fossil fuel power generation. Earth energy has an even annual load profile, with low winter and summer

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[2] The relative capital cost of an integrated GSHP/DHW/HRV decreases compared to purchasing these units separately.

peaks. Ontario Hydro has estimated a reduced load of 6.1 KW for each installed earth energy heat pump. The Canadian Earth Energy Association has reported that over 30,000 GSHPs have been installed in Canada; 75% of the reported units were in Ontario (10)

Long term environmental benefits would result from widespread implementation of GSHP systems.

ANNUAL RESIDENTIAL HEATING AND COOLING COMPARATIVE COST
New Home - Central Ontario

	Gas & AC	Oil & AC	Elect. & AC	Air Source Heat Pump	Earth Energy Open Loop GWHP	Heat Pump Closed Loop GSHP
COP=	0.93	0.83	1.00	1.90	3.80	3.50
Heating	730	1,230	2,280	1,200	600	651
Cooling	100	100	100	100	60	69
Hot Water	200	320	454	454	160	160
Maintenance	100	120	80	140	120	80
TOTAL	1,130	1,770	2,914	1,974	940	960

ANNUAL RESIDENTIAL HEATING AND COOLING COMPARATIVE COST
Older Home - Central Ontario

	Gas & AC	Oil & AC	Elect. & AC	Air Source Heat Pump	Earth Energy Open Loop GWHP	Heat Pump Closed Loop GSHP
COP=	0.93	0.83	1.00	1.90	3.80	3.50
Heating	990	1,690	3,190	1,679	839	911
Cooling	120	120	120	120	72	83
Hot Water	200	320	454	454	160	160
Maintenance	120	80	140	120	120	80
TOTAL	1,410	2,250	3,844	2,393	1,191	1,234

4.2 Super Windows

Super windows represent a major technological and architectural breakthrough. Glazing areas of conventional windows are restricted to prevent excessive heat loss. Conventional sealed double-glazed windows account for 20-25% of total heat loss in the average

Canadian home. Super windows with energy efficiency ratings greater than zero have the potential to act as solar heaters (they capture more heat from the sun than they allow to escape). Not only can such windows become effective solar collectors when properly integrated into the home, but their efficiency presents the architectural freedom to increase window areas and natural lighting levels in homes, a feature highly sought after.

Directing increased solar energy gain from super windows via an integrated ventilation/heat pump/hot water system can effectively turn super windows into solar hot water heaters, as mentioned in section 4.1.

Super windows were developed by bringing various new or improved technologies and building practices together. These include:

- low emissivity (low E) coating on the inside glazing to reduce radiant heat loss.
- new glazing materials.
- an insulating, inert gas between to reduce convection heat loss.
- insulating spacers separating panes, to reduce heat loss and condensation along edges.
- better sealing in the frame components to prevent air leakage.
- frames that transmit less heat and are narrower to admit more solar energy.
- greater durability through design and careful use of materials.
- improved installation practices to minimize air leakage around the window (12)

In a report, "Performance of Windows Used in the Advanced Houses Program", prepared for CANMET by Enermodal Engineering Ltd., super windows used in all ten houses were assessed using the HOT2000 computer program in an "as designed" context. Key insights and conclusions from the study include:

- all of the houses used low heat loss windows, with nine of the ten houses having fixed window U-values projected at 1.0 $W.m^{-2}.{}^{0}C^{-1}$ or less.
- windows in all of the houses had design values which exceeded Ontario Hydro and Ontario Building Code requirements for windows in electrically heated houses. However, many specialty products (e.g. skylights, solaria) had much lower designed energy ratings.
- the average reduction in space heating load due to solar gain through windows was projected as 19 kWh/sq.m. of floor area: 80% from super windows and 20% from solar orientation.
- had high-performance windows and good solar orientation not been used, predicted space heating loads would have doubled in five of the ten houses.

Super windows provide a key element for reducing energy demand from Canadian utilities. It appears that most consumers, commercial building owners and public building owners are not fully convinced of the potential cost benefits of using super windows. In a large part this is because such cost-benefits have not been demonstrated.

We had hoped to better identify the cost-benefit of super windows in this project but, as yet, only predicted performance and approximate cost-price information is available. Super windows are approximately double the cost of conventional windows to builders. We are unaware of any demonstration which is longer than the projected payback period. This lack of information, coupled with the possibility of durability issues (defective seals, etc) is a serious impediment to widespread acceptance of super windows.

The recent initiative by the city of Toronto to qualify the installation of super windows under the definition of "infrastructure" could possibly be replicated by municipalities across Canada. (40)

4.3 High Efficiency Gas DHW\Heat Exchanger\HRV

As building envelopes become more thermally efficient (more airtight and higher insulation levels) the required size of the heating system decreases. Small heating units are not much less in price than large heating units, so one avenue to reduce initial costs is to oversize one heating unit and to have it serve two purposes. In this regard, the use of gas fired domestic hot water heaters (DHW heaters) to provide both DHW and space heating through a heat exchanger in the intake air duct of a ventilation system reduces the requirement for both DHW and space heaters. This concept of "double duty" heaters is not new: coal, gas and wood stoves of latter years had back boilers for hot water. However the high efficiencies of current gas fired hot water heaters make the option more attractive.

The principal advantages of using a high efficiency gas fired DHW heater/heat exchanger/heat recovery-ventilation combination are:

- only one combustion unit is required.
- due to increased utilization ("on time") the heaters are 90-plus% efficient.
- the gas fuel source is inexpensive, and relatively less harmful to the environment than electricity.
- The heat exchanger system from the DHW heater to the ventilation system is a closed coil, combustion exhaust gases cannot enter the ventilation system directly.

High Efficiency Gas DHW/Heat Exchanger/HRV systems were installed in four of the Advanced Houses and one of the Healthy Houses. Despite this we have found it very difficult to obtain cost and performance information from demonstration programs and from

natural gas utilities. Gas utilities are not always straightforward in their literature about energy efficiency, for example they sometimes omit electrical energy requirements of fan motors, which can be a significant proportion of the total energy requirement.

This dual energy requirement also impacts upon the common perception that gas fired heaters are immune for electricity cuts. Small size petroleum powered electricity generators would be required for this immunization. Under normal circumstances both electricity and gas are required for such units, rendering them more prone to supply problems than single energy source units.

The absence of accurate performance information will deter the introduction of such units. However, unlike super windows, the payback appears to be shorter and the durability is less likely to be questioned by consumers.

4.4 Energy and Water Efficient Landscaping

Energy and water efficient landscapes have obvious quality of life and "Green appeal". They positively impact the environment in a multi-faceted manner and have a strong potential to bring together diverse groups such as developers, urbanists, municipalities, utilities, environmental groups etc., into win-win scenarios for concerted effort towards attaining sustainability.

After reviewing literature and interviewing industry experts it became apparent that much research has been conducted in this area, yet there are few practical plans, guides and tools available to nursery personnel, landscapers and consumers. Also, there is a lack of awareness of total operational cost savings which can be realized from energy and water efficient landscaping. The total impact of environmental innovations are only fully realized when we consider them together within the context of the house as a system; becoming a sub-system when integrated with the existing municipal and utilities grids. When considered in this manner the landscape function becomes an integral part of the overall solution for energy and water use reduction and provides a "carbon sink" for the removal of pollutants in the atmosphere.

Canadian cities and municipalities are facing budgetary constraints that are forcing some of their administrators to profoundly question traditional scenarios for housing development and the financing of infrastructure. One of our respondents, Yves Lacroix, teaches a course on municipal administration at the Ecole Polytechnique of the University of Montreal and is also the Director General of the city of Mirabel, Quebec. He recently completed a study of 117 of Quebec's most populous municipalities and his research showed that, without exception, there were no municipalities in the province of Quebec where further development has brought a reduction in taxes. This reality is forcing municipalities to consider strategies of doing more with less. The

potential medium and long term operational cost savings from energy and water efficient landscaping has gained attention.

The following table illustrates that the economies of scale may be absent. Budgets of seven small municipalities close to Longueuil are compared with the budget of the city of Longueuil. The municipal cost per capita is similar. If services are similar, economies of scale do not exist. The study produced similar results for municipalities versus cities of Laval, St. Foy, Hull, and St. Hubert. Again, if this cost side comparison yields similar amenities, economies of scale appear to be absent. (51)

Comparison of 1993 budgets of the city of Longueuil with seven neighbouring municipalities.

MUNICIPALITIES	POPULATION (1991)	BUDGET (1993)
St. Bruno de Monterville	23,849	$24,761,200
St. Lambert	20,976	$23,342,000
St. Julie	20,632	$18,927,000
Beloeil	18,516	$17,366,000
St. Constant	18,423	$15,490,000
Greenfield Park	17,652	$16,167,000
Chambly	15,893	$15,677,900
TOTAL:	135,941	$131,731,100
LONGUEUIL	129,874	$146,132,500

As taxpayers become aware of these findings and their implications on their budgets and quality of life, there will be increased pressure on elected officials to control the volume and type of development on their territory. There will also be the potential for a NIMBY, (Not In My Back Yard), reaction towards development.

Healthy, high performance housing can also affect the tax base indirectly by providing a quality comparison to other houses, whose values will decrease by comparison, thus lowering municipal tax incomes. (6) Increased scrutiny on the energy and health related aspects of houses could lead to lower market values for homes with inferior performance levels. Municipalities who have been less vigilant concerning their inspections and zoning could be left with large inventories of housing having faster rates of depreciation,

and lower tax yields. Municipalities who prioritize the implementation of healthy, high performance housing with quality of life related innovations such as energy and water efficient landscapes, will be in a much more stable position regarding house prices and municipal tax income.

Cities and municipalities are beginning to comprehend the medium and long term value of trees to their taxpayers. Projections from computer simulations indicate that 100 million mature trees in U.S. cities (three trees for every other single family home) could reduce annual energy use by 30 billion kWh, saving about 2 billion dollars in energy costs. Savings associated with avoided investment in new power supplies could augment these savings considerably.(46)

The following attributes of trees further define the potentials for energy and water related savings:

ATTRIBUTES OF TREES
- Tree shelter belts coupled with a solid fence can reduce air infiltration by 65%. (53)
- Streets with trees are 5-6°C cooler in the daytime and stay warmer at night. (53)
- By reducing runoff, trees function like retention \detention structures that are essential to many communities. Savings in stormwater management costs from trees in Tucson, Arizona were calculated at $0.18 per tree per year or $600,000 for 500,000 trees over 40 years. (13)
- 1 hectare of conifers assimilates close to 5 tons of CO_2 and releases 8 to 10 tons of oxygen per year, while the same area of grass assimilates approximately 1 ton. (55)
- Pine trees in Los Angeles were projected to remove from the lower atmosphere (under 400 metres) about 8% of the ozone and decrease the concentration around the leaves by 49%. (29)
- 1 hectare of trees traps an average of 50 tons of dust per year. (55)
- Infra-red satellite photos of the island of Montreal have demonstrated temperature differences of 6-8°C between areas with many trees and those with very few. (32)
- depending upon quantities and location, trees planted for wind break and shading functions can save 15-25% of long term heating and cooling costs.

The increased use of super windows, other passive solar acceptors, and photo-voltaic panels makes proper siting of newly planted trees extremely important to the long term performance of these technologies. From an urban planning point of view, it is also necessary to correlate the location of "preserved status" mature

trees in the proposed subdivision with solar access considerations of neighbouring lots.

The majority of research revealed that passive solar gain in winter is more important than reduction of peak summer air conditioning loads for most of Canadian climatic zones. Thus, due south tree planting in close proximity to the house should be avoided. Peak summer air conditioning loads can be addressed by trees with narrow trunks, wide crowns and slender branches planted on the southeast and southwest corners of the house, or by extended roof overhangs or window shades. Careful selection of tree species planted coupled with the use of simple inexpensive tools such as solar cards (with summer and winter solar azimuth for the appropriate latitude) can avoid considerable solar occlusion caused by bare branches and twigs of deciduous trees placed on south sides of houses. (46, 47, 48).

Combined research has shown that summertime water consumption can be reduced by a minimum of 50% if techniques for water efficient landscaping are properly applied. In general these types of landscapes include the following elements.

Maximum use of native plants, shrubs and trees
Use of wood chips and composted material to retain moisture
Selection of low water use grasses for seeding
Limitation of turf areas to recreational needs of occupants
Integration of a composting area into the plan for the site
Maximum use of unit pavers to absorb run-off water
Collection of rainwater with barrels or cisterns
Grouping of trees and shrubs in beds

When combined with the net benefits of the comprehensive integration of water reducing plumbing components, these landscapes provide significant operating cost reductions to consumers, municipalities and their local utility. Detailed analysis of the cost-benefits relating to these landscapes can be found in the CMHC study; "Sustainable Residential Developments": Planning, Design and Construction Principles, ("Greening" the Grow Home), by the Affordable Homes Program School of Architecture, McGill University. (24)

4.5 Water Purification

Water is an excellent solvent and capable of containing many chemical impurities. Water also comprises about 70% of the content of human bodies, and imbibed water impurities will enter humans.

Water impurities, particularly those which might be retained and accumulated in the body, should be reduced to as low a level as possible. Water purification is a key ingredient for healthy, high performance housing. Proper follow-through of water related innovations would lead to cost effective reductions of residual amounts of persistent toxic substances in Canadian drinking water. The accumulation of harmful impurities in water was highlighted in the Seventh Biennial Report on Great Lakes Water Quality by the International Joint Commission (February 17,1994). The report and press release, "calls on governments, industry and others to adopt a new way of thinking about persistent toxic substances". The Commission concludes that this is the most significant problem facing the Great Lakes Basin. Mounting evidence reinforces concerns that exposure of fish, wildlife and humans to persistent toxic substances such as hexachlorobenzene, PCB, DDT, dieldrin and others is linked to long term reproductive, metabolic, neurological, behaviourial and intergenerational effects. Latest research findings point to possible human effects such as startling decrease in sperm count, an increase in male genital tract disorders, increases in breast cancer at epidemic rates, and declining learning performance and increasing behaviourial problems in school children."

The Commission's report can be considered as an opportunity to focus efforts on identification of short and long term strategies to reduce the risks to human health associated with water-borne substances. It is also important to note that water is not the only source from which we absorb these substances, since they bio-accumulate in the food chain and some are found in the air.

The reverse osmosis systems with activated charcoal filtration being demonstrated in some of the Healthy and Advanced Houses are a short term solution for the elimination of impurities at the individual household level. Implementation of the water conservation innovations demonstrated in recent housing programs could eventually reduce volumes sufficiently to make medium and large scale supplementary water filtration more affordable for the average Canadian municipality.

Comprehensive testing of home water treatment devices has been done by the consumer protection group "Protect Yourself" in 1988 and by the Department of Health of the City of Toronto in 1990.[3]

The "Protect Yourself" study compared the performance of carbon filters, ceramic filters, distillers and reverse osmosis with carbon filters. The Toronto study compared the quality of the water in bottled, tap, and that treated by home treatment devices. (30, 61)

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[3] "Protect Yourself" is currently undertaking testing in preparation of an updated report on water purification systems.

Both studies suggest that under good operating and maintenance conditions, reverse osmosis combined with activated carbon filters greatly reduce levels of the more toxic contaminants in water. The Toronto study identified the need for frequent and qualified maintenance to prevent build up of bacteria within home water treatment devices.

High performance units such as the model selected for demonstration in the Novtec Advanced House did not indicate a bacterial build up problem in "Protect Yourself" tests, however these units are sold with a home maintenance contract and cannot be strictly compared to off the shelf units where the home owner undertakes the maintenance.

5.0 IDENTIFICATION OF OPPORTUNITIES AND OBSTACLES

5.1 Questionnaire

The questionnaire used is contained in Appendix A.

The single most important finding resulting from this questionnaire is that most of the respondents were not fully informed. For the most part this is not because they had not received information but because had received too much documentation. It appears that they could not manage to prioritize, nor read and retain the information.

INFORMATION OVERLOAD appears to be the single most important obstacle to our industry. We perceive a very real need to reduce the quantity of documentation and to increase the quality and breadth of distribution of technical information.

Questionnaire responses are summarized below.

5.1.1 Re: Opportunities Identified

Government

Thirteen (13) out of thirty two (32) responses on opportunities related to government. For the most part these were aimed at opportunities to overcome existing obstacles:

- reducing the cost and time required for acceptance of new products vis a vis building codes and material standards.
- provision of a more flexible "fast track" through regulations for product approval.
- funding incentives for demonstration and commercialization of environmentally sustainable high performance products.

Awareness

Ten (10) of the remaining nineteen (19) responses related to

training and demonstrations aimed at increasing awareness of advantages of using environmentally sustainable high performance products and systems. Three of these responses stated that cost advantages must be clearly identified.

Others

Nine (9) responses related to placing emphasis on individual products and concepts. There was no commonality to the specifics.

5.1.2. Obstacles Identified

Resistance to Change

Fourteen (14) out of forty seven (47) responses related to the industry's resistance to change. Reasons were:

- fragmented industry cannot produce coordinated effort for change.
- poorly trained and educated workforce is not adaptable to useful innovation.
- poor "big picture" view of what's good for society as a whole.
- houses = high investment = low risk acceptance for most home builders and home buyers.
- complexity of some innovative structures and equipment.
- lack of imagination and short term focus of the industry.

Fuzzy Benefits

Ten (10) of the forty seven (47) responses related to inability to clearly and convincingly define the benefits from using environmentally sustainable high performance products and systems.

- advantages, performance and cost benefits of innovations not clearly identified to consumers: in many cases the performance and benefits are not yet known.
- performance concerns about new products and new product manufacturers generate concerns about payback and product support.
- lack of education of consumers regarding benefits.
- existing industry stakeholders and financial institutions place environmental innovations in the "left wing - mad scientist" category for self-serving reasons.

Government

Ten (10) of the forty seven (47) responses related to government. Four (4) of these related to the use of regulations to prevent change.

- building codes and product standards are used to maintain the status quo, preventing innovation and new product

introduction.
- government services large energy utilities (hydro, coal, gas, oil) to the detriment of solar and wind innovations.
- low R&D spending. [Also a criticism of private industry].
- lack of official backing of innovations from government.
- industry attitudes which have developed for subsidies.

High Costs

Eight (8) of the forty seven (47) responses related to high costs.

- demonstration projects are associated with "pie in the sky" costs.
- front-end costs are very high for energy efficient windows and heating systems.
- perceived costs higher than real costs.
- concern over high maintenance costs.

Others

Five (5) out of the forty seven (47) responses related to other areas. Two obstacles mentioned were:

- lack of consumer demand for environmental products, but Canadian youth more in-tune with environmental requirements.
- current stagnation of construction market.

5.1.3. R-2000, Healthy House & Advanced House Demonstrations

This questionnaire was sent to building industry participants and yet three (3) of twelve (12) respondents did not know of these programs.

Seven (7) out of twelve (12) respondents indicated that they had received little to no information about these programs.

Three (3) of the five (5) respondents who had received more information said that their associates were largely ignorant of these programs. They suspected that information had reached CHBA, CMHC and EMR but few others.

5.1.4. Comments on Innovations Selected

Passive solar was emphasized: south facing lots, shading and EE windows relate to this.

Two respondents questioned the need for water purifiers, in their belief that municipal water was of adequate purity.

It was noted that changes in building codes and practices will be required to facilitate the introduction of many of these innovations.

5.1.5. National Critical Path

Eight (8) of eleven (11) respondents said that a national critical path was necessary or desirable to accelerate environmentally sustainable high performance housing. Some comments were:

- required to counterbalance specific interest groups, eg. established product manufacturers and utilities.
- needs to be free from lobby groups and bureaucratic processes.
- required to add global perspective, and to initiate vast education (through schools, colleges, etc).
- encourage financial credits for use of environmentally responsible high performance products (lower mortgage rates, energy rates, municipal taxes, health insurance rates).

Two (2) of the three (3) negative responses equated a national critical path with government and large industry. They believed that this would only increase taxes, reduce innovation and deter new product introductions.

5.1.6. Other Comments

The following six comments were thought to be particularly relevant to this study.

- strengthen the study by use of case histories.
- do not initiate other programs like the "rag bag of innovations" used in Healthy Housing and Advanced Houses demonstration programs.
- information on innovations is largely restricted to annual expositions, need more frequent and widespread information dissemination.
- form round table for discussion of project, to bring focus and precision to the ideas.
- use higher rates for municipal services to generate awareness of real cost for services.
- slowness of the building industry response to government and utility initiatives on energy conservation in the 70s and 80s was cited as a reason for using code changes to introduce innovation.

5.2 Supplementary Documentation

Acting upon the recommendations of our industry respondents and realizing that the opportunities and obstacles identified would need further quantification from an industry readiness point of view, supplementary documentation pertaining to the scenario of implementation was reviewed. Previous case studies and testing pertaining to the selected innovations was co-related into the study to assure that factors such as economies of scale would be adequately considered when determining ways to accelerate their implementation. (10,25,30 etc.)

5.3 Supplementary Interviews

In parallel to the assessment of the supplementary documentation, interviews were held with resource persons directly involved with the day to day implementation of the innovations and their communications related obstacles. (Appendix C) Factors relating to manufacturing and operating costs, market potential, documentation and training were also reviewed to assure proper focusing of the strategies for overcoming obstacles.

5.4 Table of Opportunities and Obstacles

Two major opportunities and obstacles for the five selected innovations were identified.

INNOVATION	OPPORTUNITY	OBSTACLE
GSHP\HRV\DHW CONFIGURATIONS	Increased simplicity and unit cost reduction with increased implementation	Initial high cost limits its widespread use
	Up to 400% efficiency and integrated multi-functionality = safest and cleanest, (from air quality & environmental) use of major fuel source	Complicated installation
SUPER WINDOWS	Higher performance than that perceived in the marketplace	High initial and replacement costs\ lack of long term performance data
	Costs can be reduced by increased production and sales	More cost effective ways to retrofit building envelope need to be exhausted prior to installing super windows
HIGH EFFICIENCY GAS DHW\HEAT EXCHANGER\HRV	Use of widely available low cost fuel.	Market will be limited to regions where natural gas is available
	Higher performance with reduced capital and operating costs. Good retrofit potential.	Consumers see high initial costs and complexity\maintenance related problems
ENERGY & WATER EFFICIENT LANDSCAPING	More collaboration between stakeholders will accelerate the scenario for implementation.	Stakeholders are largely unaware of the benefits of the mass application of the innovation
	Obvious "Green Appeal".	Some local officials perceive that environment related changes are too costly
WATER PURIFICATION (REVERSE OSMOSIS\CARBON FILTER)	Mass implementation will reduce unit costs substantially.	Majority of consumers are unaware of a potential water quality problem
	Demand side management and segregated use of water will make large scale systems more affordable.	Large volumes of water currently needed for fire fighting inhibits increased purification of water at the municipal level

6.0 WAYS TO ACCELERATE IMPLEMENTATION OF INNOVATIONS

6.1 GSHP\HRV\DHW

6.1.1 Ways to Capitalize on Opportunities

Opportunity 1. Increased simplicity and unit cost reduction with increased implementation:

For an earth energy heat pump manufacturer, buying components in quantities of 10 is 17% less costly per unit than buying 2 to 5; and buying in quantities of 100 is 28% less per unit. Beyond 100, the incremental savings diminish, but large manufacturers can have unit costs 30% less than small manufacturers. The U.S. Department of Energy indicates that total first costs (including installation) can be reduced by about one-third with sufficient sales volume. In the increasingly competitive marketplace, these volume savings will result in lower prices to the consumer. (10)

Further research and development should focus on the potential for simplification of the technology. The components in the heat pump are very similar to those in a refrigerator.

Opportunity 2. Up to 400% efficiency and integrated multi-functionality results in the safest and cleanest (from an air quality and environmental criteria) use of a major fuel source:

From both operating and environmental cost viewpoints, GSHP/DHW/HRV systems can be the most responsible option for home energy needs. This environmental cleanliness of electrically powered units is contrary to conventional thinking, because electrical energy is both costly and has a relatively high environmental demand. However, tapping into earth energy (a low cost, environmentally pristine energy source) results in a multiplication factor of purchased electricity by a factor of 3 to 4. If the efficiency of the electrical grid is 30% (including both generation and transmission losses), connecting to a high efficiency earth energy heat pump with a COP of over 3.3 brings the efficiency of the whole system to over 100%. Even in the worst case of coal fired generation, the CO_2, NO_x and other emissions per kWh generated are divided by 3.3 (or more) per kWh delivered by the earth energy heat pump. The emissions per unit of energy delivered are less than those of a natural gas delivery system in global warming potential. (10)

These benefits need a higher profile in the marketplace and a more prominent position in the national policy for combating global warming. Earth energy should be recognized as a "green industry" and heat pumps be considered for a "green products" category. Recognition of this nature would improve their position in the marketplace and further accelerate their implementation.

There is an opportunity for complementary marketing within a "green" context between the GSHP contractor and the landscaper to provide comprehensive energy and water efficient landscapes. This is attractive because, at the same time that underground loops are installed for ground source heat pumps, the landscape can be upgraded to a low water, energy efficient one.

6.1.2 Ways to Overcome Obstacles

Obstacle 1. Initial high cost limits widespread use.

An earth energy system is presently in the category of a premium product. It demands a premium price on the market as an environmentally sound, integrated space and hot water heater and space conditioner. Its components and complexity make it unlikely to reach installation cost parity with simpler, less versatile, higher operating cost conventional systems. Thus, overcoming this initial obstacle will necessitate addressing the high end market first, with the diffusion rate accelerating as competitive energy costs increase and R & D related cost reductions are implemented.

The new units coming on the market have been designed for easier installation. Over 95% of units sold add a duct heater, hot water superheater and pump which can be installed at the factory. To add these options takes four hours in the field at $65\hour in addition to the dealer markup on parts, or two hours at $20\hour in the factory in volume. Well designed installation kits and accessories can save another two hours of field installer time. Thus, the customer can save $350 just by better installation design and factory installed options. Economies of scale are also possible at the installer level. Recent experience where more than 30 units were sold at the same time resulted in a total savings in excess of $2,000. (10)

The obvious way to overcome first cost obstacles is to use financing. Gas utilities will finance installation of energy efficient systems through increased monthly billings, in some cases the increase is small as energy savings off-set the capital and interest payments. It is not clear why electricity utilities do not undertake such programs.

Obstacle 2. Complicated installation

Ground source heat pump installation has high skill requirements which require proper training and experience. The trenches needed for horizontal installations of the spiral coils need sophisticated backfilling techniques (with sand) with close supervision by the installer to assure proper underground support for the loop. Also spiral coils require careful purging to ensure that all air pockets are excluded from the coil's spirals.

The recent Ontario Hydro\CEEA program warrantee experience is that the greatest source of problems by far were inadequate design, where ground loops were too short, and inadequate loop installations. (10)

Canadian Standards Association documents CSA C445 and C446 go some way to overcoming this obstacle, however more information such as comprehensive installation manuals with detailed videos for training and the up-grading of present techniques will help. Designers and installers also need design software that includes engineering data and algorithms for field sizing.

An installation breakthrough, (60% saving in trenching), is the SVEC spiral coil developed by NRC and used in some Advanced Houses. A typical SVEC (named after its founder) has the potential of saving $100 per installed kW through the use of shorter trenches. It also provides the added benefit of making installations possible on smaller lots. (10)

6.2 Super Windows

6.2.1 Ways to Capitalize of Opportunities

Opportunity 1. Higher performance than that perceived in the marketplace.

Renovation and rising energy costs present an opportunity for high-performance windows if their benefits are properly presented to homeowners. Computer simulations for Advanced Houses indicate that the passive solar contribution (from reduced window heat loss and solar orientation) for five of the houses is approximately equal to the total heating load. The passive solar contribution can be thought of in two parts. The first part (80%) being the reduction of the heating load due to the use of high-performance windows. The second part (20%) being due to increased window area on the south side. This superior performance is generally not recognized and represents a marketing opportunity.

Opportunity 2. Costs can be reduced by increased production and sales.

The certification program for high-performance windows will lead to higher sales through provision of better and more reliable customer information, which will include reliable and credible methods of comparison for window selections. However, the certification process represents a significant investment for Canadian manufacturers.

This is an example of the chicken and the egg syndrome, where costs have to be paid by manufactures prior to receiving benefits. The manufacturer is burdened with the added expense of a potential

mandatory certification process without sufficient support from other stakeholders, who have quantifiable benefits to be reaped if certification is accomplished. Capitalizing on the opportunities surrounding the comprehensive certification of high performance windows will involve renewed support from the utilities, all levels of government and a streamlined regulatory process.

Demand-side management studies have indicated that massive implementation of super windows can make a significant contributions to reduced energy use in both new and retrofit housing. Accelerating the use of super windows will help Canada to meet its United Nations climate change treaty obligations and accelerate the transition to renewable sources of energy.

Many consumers purchase super windows for comfort and quality of life considerations. Increased daylighting is one of the most desirable attributes for many homeowners. For the elderly, moderately higher humidity levels are very important and these windows will permit this without the problem of condensation. Value added benefits of this nature are an important incentive for choosing high performance windows.

6.2.2 Ways to Overcome Obstacles

Obstacle 1. High initial and replacement cost coupled with lack of long term performance data.

As mentioned previously in this study, consumers are preoccupied with first costs and the fastest payback period possible. The homeowner is also concerned with replacement cost associated with accidents.

In new houses, the placement and sizing of super windows help reduce costs required for primary heating sources. This integrated approach will lead to initial costs which are less than the straight window-to super window comparison, and can lead to increased daylighting and comfort.

At the moment super windows sell at approximately double the price of conventional windows. As super windows become more commonly used their manufacturing cost will decrease and, in a competitive market, their price would be expected to decrease proportionately.

In the absence of proven long term performance, manufacturer guarantees or manufacturer association guarantees could be used to alleviate customer concerns about lack of proven long term performance. Given the distrust of manufacturer guarantees, especially from small manufacturers, an association backed guarantee is probably a more useful marketing tool.

Obstacle 2. More cost effective ways to retrofit building envelope need to be exhausted prior to installing super windows.

In retrofit situations the possibility to integrate super windows into the overall house design (location and placement of windows, heating system sizing, etc.) is not usually possible.

In retrofit, it is generally more cost-efficient to increase the energy efficiency of the opaque portion of housing envelopes (solid walls, roofs) or to increase the efficiency of heating units, than to replace windows with super windows. This is especially true if window sizes and positions cannot be easily changed (eg. due to masonry exteriors or inside partitions). Indeed the solar gain potential of windows might be lost if the remainder of the building envelope was inefficient and "leaked" the solar gains.

Previous energy efficiency programs have identified the primary heat loss areas for all types of housing. Generally accepted levels are; 10% to 15% for attics, 20% to 25% for basements, 10% to 20% for walls and 15% to 20% for windows. Consumers will in most cases will choose the least cost, obvious benefits options before moving to those which involve a long term perspective and higher first costs. Overcoming this obstacle will involve providing less complex, easily understood information to consumers on the process of selecting the appropriate high performance windows for retrofit and new housing. The information should include correlation to housing type and year of its construction, efficiency benefits in relation to payback periods and criteria for evaluating the manufacturer's long term performance warranty.

Previous studies by Ontario Hydro and Hydro Quebec have analyzed the cumulative effect of different combinations of techniques and components affecting the overall efficiency of housing. In terms of windows dual seal windows have the shortest payback period, followed by low E windows. Gas filled windows were rated last.

Given that gas filling of multi-pane windows is reported to cost approximately $1 per square foot of glass, the utility studies may be simple minded, in that the combination of multi-pane, low-e and gas filled widows (ie. super windows) yields better paybacks.

Solarium additions offer a possibility to add better daylighting and a "solar heating system" to many houses. Solid masonry walls can act as heat storage in such situations, with air ventilation transferring heat to other areas of the house. A light open sun-space is an attractive feature for many houses with limited fenestration.

We believe that sun-space additions, which primarily feature quality of light and secondarily feature energy efficiency, are a way to accelerate entry into the retrofit market.

6.3 High Efficiency Gas DHW\Heat Exchanger\HRV

6.3.1 Ways to Capitalize on Opportunities

Opportunity 1. Use of a widely available low cost fuel.

In terms of cost per unit of energy, natural gas costs approximately 35% that of electricity in Ontario. Costs comparisons differ between provinces, but in all provinces where gas is available it is significantly cheaper than electricity. The environmental impact involved in generating and distributing electricity is also approximately 3 times that of distributing gas fuel to homes.

The obvious way to capitalize on this is to distribute gas to more places. A less obvious way is to compete with electrically powered heat pumps. The Innova Advanced House demonstrated this type of equipment as an air-conditioning system: a gas engine was used to run the compressor. Either directly through an engine, or via a gas fuelled power generator, the development of an entirely gas based heat pump system is possible.

Opportunity 2. Higher performance with reduced capital and operating costs. Good retrofit potential.

Gas-fired water heaters combined with heat exchangers and HRVs in integrated systems approach provide up to 94% energy efficiencies and reduced operating costs. These lower operating costs are made possible, in the case of the Innova Advanced House, by the use of energy efficient motors and the direct venting of combustion air. The central air blower uses a prototype electronic commutated motor (ECM) that reduces the electricity consumption by up to 40% compared to a conventional fan motor, and the HRV uses an energy efficient motor with saving of approximately 20%.

6.3.2 Ways to Overcome Obstacles

Obstacle 1. Market limited to where natural gas is available

In order to amortize long term financing for the extension of the grid into proposed or existing residential developments, gas companies must have sufficient numbers of long term customers. Their gas consumption must also be high enough to generate revenue for grid maintenance.

In Quebec, existing customers are given a surcharge if they reduce their peak period consumption through the integration of high performance electric heat exchangers. This surcharge is based on a complicated criteria for matching the peak load electricity rates with the rates for natural gas with automatic switch over to gas occurring when outside temperatures are sufficiently cold to place the electrical grid in a peak load position.

Overcoming this obstacle will involve the simplification of the available information available to consumers so that they will be able to clearly perceive the short and long term advantages of locking themselves into dependence on natural gas as their primary energy source. By educating consumers on the benefits of gas technologies and providing a regulatory context which maintains stable prices, expansion of the grid can be assured.

Obstacle 2. Consumers see high initial cost and complexity\maintenance related problems.

The majority of consumers are primarily concerned by first costs and want to recover their investment as soon as possible. This problem is amplified if the homeowner does not intend to remain in the residence for an extended period of time. The perceived lack of price stability in the housing market adds to the uncertainty surrounding opting for an integrated system.

When integrated systems are perceived as being complex, more assurances must be given to the buyer that the benefits of the systems outweigh possible maintenance problems in the future. This obstacle can be overcome by providing home buyers with precise information concerning the sometimes high parasitic energy requirements of less efficient fans, motors and controls, which inhibit a clear understanding of the system's long term viability. The real operating\efficiency related costs must be made extremely clear to the purchaser or further diffusion of the system in the marketplace will be delayed. More transparency in communications concerning maintenance costs and selection of the most efficient components available for integration into the systems will help to assure the long term success of marketing initiatives.

Another factor affecting the diffusion of these systems is a lingering fear of natural gas which has been re-kindled recently by media coverage of California earthquakes. Even though this fear may be statistically unfounded, it remains an obstacle for the marketing of natural gas integrated systems in some regions of Canada. It can be overcome by emphasizing the existing safety mechanisms in present equipment and clarifying the seismic activity level of the host region for the gas grid.

6.4 Comprehensive Energy and Water Efficient Landscaping

6.4.1 Capitalizing on Opportunities

Opportunity 1. More collaboration between stakeholders will accelerate implementation.

Capitalizing on this opportunity for will demand a higher level of cooperation between all participants in the application of the Green Plan. This process will entail identification of how each sub-program in the plan compliments the others. An accelerated

transfer of working models and methodologies between each sector of activity relating to the housing industry will also be needed. There are numerous examples of existing models and complimentary sub-programs. Some of the outstanding ones include the following:

- Most Canadian utilities have subsidized the replacement of inefficient motors for the pumps installed in municipal infrastructure by high efficiency models. In Quebec, Hydro Quebec is now becoming involved with programs for water-use reduction at the municipal level through direct collaboration with the environment departments of cities such as Laval. It is beyond the scope of this study to analyze the long term benefits of stabilizing the demand load for pumping municipal wastewater. However, since the demand side management benefits for both the utility and the municipality are already being quantified in a holistic manner in these programs, the addition of further criteria concerning the benefits of appropriate landscaping techniques for water use reduction will have less resistance to their implementation.
  By participating in energy and water efficient landscape initiatives, utilities will also be able to reduce their maintenance and generation costs by assuring that the trees planted will be in optimal locations for reduction of winter\summer peak-demand periods. Also they can ensure proper placement of trees in relation to existing and future transmission lines.
- The existing composting programs in Canadian municipalities reveal that reductions of up to 30% in the waste stream can be realized if property owners are well trained and there is appropriate follow through on communications. When local re-greening projects become interlinked with local compost production projects, the locally produced compost will feed the newly planted trees. This saves transport costs of pick up, trucking to centralized sites and re-trucking back as finished compost. When housing is clustered around common green spaces, medium scale composting techniques can be used to provide natural fertilizer to the trees and vegetation comprising the landscape.
- Model municipalities such as those involved in the Ontario Green Communities Program can increase the sharing of proven projects and techniques using exchange models such as the Mega-Cities Project. Cities involved in this network transfer working model projects and their accompanying innovations from one participant to another, thus reducing the costs for replication of the original intervention and encouraging continuous development and upgrading of performance. This process also has the salient effect of forcing consulting and engineering firms to seriously consider applying proven innovations or they risk not keeping pace with the continuous improvements made on the original model. (60) The Federation of Canadian Municipalities and their provincial counterparts are ideal vehicles for disseminating replicable model programs

among their memberships.
As we cluster the complimentary sub-programs around the need for accelerating the implementation of the innovations, the critical contributions of the building industry, utilities, NGO's, and governments are much more apparent.

Opportunity 2. Obvious "Green Appeal"

Capitalizing on the opportunity of the obvious green appeal of the innovation involves continuing to support the momentum created by the demonstration programs through comprehensive communication and information programs informing the public on the benefits of water and energy efficient landscaping.

There are a multitude of landscape related, re-greening programs across Canada involving thousands of consumers who will support the transition to energy and water efficient landscapes, if they are provided with detailed cost-benefit information and how-to guides explaining the techniques for planting.

Many municipalities now have environment committees which coordinate the composting, tree planting, and recycling programs in their communities. They also make recommendations to their municipal council concerning development-related issues affecting the quality of life and environment of the taxpayers. In most cases, the local schools, Scouts, and service clubs are interlinked with the activities of these committees. The Landscape Ontario Horticultural Trades Association has been effectively using these committees for the dissemination of their information brochure; "Landscaping for Energy Conservation". This brochure was based on the energy efficient landscape of the Brampton Advanced House. Alliances of this nature enable industry to present innovations to large numbers of consumers at low cost.

6.4.2 Ways to Overcome Obstacles

Obstacle 1. Unawareness of environmental and dollar cost savings by reducing infrastructure dependence

As mentioned earlier in this study, research is indicating that Canadian municipalities are approaching the point where they have no other choice than to accomplish more at less cost to the taxpayer. The viability of continuing to install traditional infrastructure is questionable from both economic and environmental perspectives, at least without consideration of innovative modifications. Alternative strategies exist, and there are strong indications that they could prove to be economically and environmentally more attractive. The combination of grey water re-use, water efficient landscaping, and other innovations which reduce dependency on infrastructure could prove to be economically and environmentally viable alternatives, if considered from a long term perspective.

The majority of developers and builders are presently using sod with high water consuming species of grasses for final landscaping before the sale of new homes. Without direct intervention via new municipal regulations, re-orientation of the industry towards acceptance of seeding with low water use grasses as a viable alternative will be difficult, despite the fact that it can reduce the developers landscaping costs by up to 50%. The results of not making the transition are that higher water usage costs are transferred to the rate-payers.

Present municipal tree preservation laws are inadequate and municipalities lack the financial resources to improve their capacity to monitor their territory and provide supplementary training for their employees. Some developments in forested areas retain adequate numbers of mature trees but compaction, excess topsoil over roots, and injury to the bark cause large numbers of these trees to die within the first five years of the project's existence. This loss eliminates the contribution trees make as living storm water retention\detention devices resulting in higher costs and lower efficiency for the waste water treatment plant. Also lost are the energy efficiency gains and the higher evaluations possible through the quality of life related attributes of trees.

A comprehensive awareness of the short and long term benefits of energy and water efficient landscapes will lead to modification of present municipal regulations to accommodate the preservation of existing mature trees, precise guidelines for the planting of new ones and a gradual transition to low water use landscaping techniques.

Obstacle 2. Some local officials perceive that environment related changes are too costly.

Local officials are charged with economic prudence and, conventional wisdom equates environmental improvements with increased costs. This is correct in a minority of cases and most environmental improvements related to housing also result in economic improvements.

The level of environmental awareness of municipal officials is generally increasing alongside that of the general population. Local voters are progressively eliminating municipal officials whose level of resistance are affecting their quality of life.

The following examples assist in overcoming this obstacle:

- The tremendous dollar value of grass roots voluntaryism is under quantified from an economic viewpoint, from both a short and long term perspective. Most urban re-greening projects on public lands have an average "delivered" value 50% greater than their initial funding, when comparative (municipal

employees or sub-contractors) labour costs are factored in. This is without factoring in the long term benefits of better air quality, shading and aesthetics of public buildings, and the higher evaluations the combination of these benefits achieve.

- The species of grasses used for seeding low water consuming lawns require less frequent cutting therefore providing the incentive of reduced maintenance for the homeowner and the added benefit of reducing the smog levels from power mowers in urban areas. The amount of grass clippings entering the waste stream is significantly reduced for municipalities lacking composting programs.
  This principle is also true for zoning for protection of mature trees and solar orientation in proposed subdivisions. Without direct municipal intervention via specific regulations and guidelines addressing optimal locations for new trees, preservation of existing ones and the use of low water use grasses, the existing inertia and "laissez-faire" attitudes could overcome any local initiatives to apply innovations.
  The challenge of attaining sustainable development will necessitate close scrutiny of the long term tax-related effects of traditional scenarios for development. Speculation with and development of municipal territories, is a privilege and "not" a right. The interests of the existing citizens and their long term tax and quality of life related considerations take precedence over the temporary presence of developers, since in the long term they will have to absorb all future costs for the inadequacies caused by the application of old methodologies and short-sightedness.

6.5. Water Purification (Reverse Osmosis\Carbon Filter)

6.5.1 Ways to Capitalize on Opportunities

Opportunity 1. Mass implementation will reduce unit cost substantially.

The opportunity for mass implementation was identified by our industry respondents as the most important means for reducing manufacturing costs and increasing R&D for small scale high performance reverse osmosis\carbon filter water filtration systems. The retail cost for these units can be reduced by a minimum of 40% once sufficient volumes are achieved.

Even with the benefits of mass implementation, the retail price of these units will be $500.00 or more. This places them beyond the means of the average consumer without significant subsidies.

There are many insights used for the development and diffusion of the HRV (Heat Recovery Ventilation) units that can be applied to the scenario for reverse osmosis\carbon filter water treatment devices. There is the potential for following a similar strategy

for the opportunity for the acceleration of their implementation.

A substantial number of HRVs were sold in the 80s to solve problems associated with houses having increased airtightness, and the R-2000 Program continued their diffusion. The standards for HRVs were developed fairly rapidly, not because of consumer demand, but as a result of the intervention of government agencies such as EMR and NRCC. Standards evolved from a combination of the work of various ASHRAE, HRAI, and CHBA committees on ventilation, heat recovery and indoor air quality and of the R-2000 HRV testing program at Ortech Corporation. (25)

As a result of the sustained government involvement in the HRV R&D and diffusion process, there was a strong flow of communications between researchers, manufacturers, and concerned government departments and industry associations. This was a good example of successful cooperation between government, industry and trade associations. As a result of this cooperation, there are now viable products, a trained core of tradespeople and a balanced regulatory environment. (25)

The same level of cooperation which facilitated the diffusion of the HRVs can be replicated for the water purification sector. The recognition of the air quality problem was instrumental for focusing further R & D and the streamlining of the regulatory process. The recognition of the present water quality problem in some regions of Canada can lead to a multi-faceted approach to focus efforts on implementing short and long term solutions. This approach can profitably use the model provided by the HRV's implementation path and further accelerate its diffusion process.

Opportunity 2. Demand side management and segregated use of water will make large scale systems more affordable

Large scale biologically activated carbon water filtration systems and reverse osmosis systems are very costly as their specifications and sizing are directly related to the quantity of water to be treated. The combined result of using water reducing plumbing fixtures and low water (Xerscape) landscaping techniques, can lead to lower volume and lower cost for municipal water purification systems.

Capitalizing on this opportunity will be contingent upon the action based the following examples taken from previous studies:

- Harmonization of Canadian-U.S. standards is needed to cost effectively deliver water conserving technologies to the marketplace. Due to the vested interests of established manufacturers and the limited resources for standards research and development, it is likely that proponents of water conservation will have to provide significant funding to

accelerate the development of meaningful, harmonized standards which result in affordable testing of available technologies. (21)

- There is a need for comprehensive research of economic impacts associated with water conservation, (ie., development cost, building costs, utility and infrastructure life etc.) A fuller understanding of this relationship will permit a more appropriate approach to R&D, demonstration and implementation. (21)
- Continued population growth is expected in Canada, this will place continued pressure on existing and future housing stock and infrastructure. A plan to address serious capacity and affordability problems in the future is urgently required. The challenge of providing municipal infrastructure cost-effectively for present and future Canadians may appear daunting now. However, we should not allow our traditional entrepreneurial tardiness to prevent us from exploiting the benefits of research carried out here and elsewhere. Solutions should be based on new technology rather than old methodology. We should selectively confirm the cost-effectiveness of our new infrastructure products, building on what has been already done and aggressively seek to establish a competitive advantage for Canada in this area on a world scale. Alternatively, what will be the quality and affordability of housing for 50 million people in Canada in 2031, if 80% of these people live in substantially urban areas. (70)

6.5.2 Ways to Overcome Obstacles

Obstacle 1. A majority of consumers are unaware of problems with water quality.

Technological advances in the area of water quality analysis have increased our capacity to measure small amounts of chemicals in our water supplies. These advances, and recent epidemiological studies of the effects that bioaccumulation of these substances has in our bodies, indicate that there may be more long term danger to public health from these substances than previously indicated. Pro-active, concerted effort by government and the health industry with the collaboration of the housing sector, could reduce potential long term health related costs.

The average consumer is confronted every week with media reports, with commentary from experts representing both sides of the issues in often contradictory terms. The general reaction is an "information overload" syndrome, where the consumer becomes suspicious about the issue in general. This resistance on the part of the consumer makes home water treatment systems difficult and expensive to market. Interviews with consumers in the study, "Consumer Housing Choices and the Environment" revealed that less than one third of participants selected water purifiers as a priority option. Our interviews with industry respondents has

confirmed this reality. (16)

Increasing the quality and credibility of information directed to the consumer will increase the public's awareness of this issue and, consequently, increase market demand. Verification of performance levels and the eventual certification of these systems by appropriate regulatory agencies will act as accelerators for their implementation.

Often, large building material and hardware distribution groups are searching for environment-related innovative products that will enhance their image with existing clients and attract new customers to their stores. In most instances the product is introduced with an educational marketing approach which includes demonstration in the stores and Home Shows. Alliances between the innovator and these groups can significantly reduce market entry costs and accelerate the diffusion process for the product or technique.

Obstacle 2. Large volumes of water currently needed for fire fighting inhibits increased purification of water at the municipal level.

The persistent problem of using potable water for fire fighting will inhibit upgrading of existing municipal water treatment systems since advanced large scale filtration systems are very costly and such treatment of the large volumes of water required for fires could be cost prohibitive.

Further research is needed on the potential for segregating water for fire control from that intended for human consumption. Possibilities include; modifying present storm sewer drainage systems by integrating holding basins connected to separate fire lines for new developments, re-thinking zoned sprinkler systems for residential housing in relation to cisterns with long term insurance costs factored in, and the use of non-toxic foam techniques for fire smothering.

In 1989, Hickling Management Consultants, prepared the study, "Technology Transfer and Innovation in the Canadian Residential Construction Industry" for the CMHC. We are presenting the recommendations from this study in their entirety to compare the perceived opportunities for acceleration of the diffusion process of innovations in 1989 with the perceived opportunities for 1994-95.

Recommendations from the Hickling Study:

1. Credibility of source, importance of peers, large numbers of small builders, risk aversion, etc., points to the necessity for government and industry to concentrate on developing communications within the industry and encouraging exchange of information on new products.

2. One excellent opportunity occurs when builders gather in large numbers at their annual convention. The industry should make "technological innovation, new products and techniques" the theme of one its forthcoming annual conferences.
3. CMHC\Industry Associations should further strengthen the regional\local networks of local builders. The strengthening of these networks could be achieved by encouraging regular meetings\workgroups between CMHC regional\local staff, appropriate staff from NRC\EMR and local builders for the purpose of discussing issues related to recent innovations and other issues of importance.
4. The risk aversion of builders and other LRRCI(low rise residential construction industry) participants suggests the usefulness of including up to date diffusion related information (who is using what, where and their experience). This information tabulated by type and size of users, as well as by geographical distribution should be incorporated into NRC's Canadian Construction Information System (CCIS) and in CMHC workshops.
5. Construction Centres should provide excellent vehicles for the transfer of new ideas. Federal government agencies should be in a position to provide advice, assistance and work with provinces, local building associates, etc. in establishing such Centres and insuring linkage between them.
6. The high level of risk aversion, i.e. the desire not to be the first to adopt an innovation, suggests that "demonstration" is an important diffusion accelerator. CMHC should consider initiating a demonstration program in coordination with industry to demonstrate worthwhile innovations in techniques and products.
7. This study demonstrated the relatively unimportant role played by buyers in the diffusion process because of lack of information. The government should take the lead in sensitizing the consumer to the long term implications of his purchase decisions. CMHC Brochures\Seminars for new purchasers and the availability of selected CCIC information to the consumer, media and consumer groups would go a long way towards bringing consumers more fully into the diffusion process.
8. Both government and industry should take steps to identify and publicize innovations. CMHC's "job site innovation program" is a step in this direction. Government and industry should consider the production of brochures for each trade, describing new ideas and techniques to improve practice and increase productivity. These could be updated on a regular basis.
9. Given the complexity of the process of technology transfer, it is apparent that efforts to facilitate transfer, to be effective, must adopt a multi-pronged and fully integrated approach. This must take into account education and training, marketing, the interface with other components of the production process, and consideration of codes and standards.

It is evident that there has been significant follow-through on a number of the above mentioned recommendations. However, we have found that during the ensuing time period the challenge of attaining sustainability has itself become a significant diffusion accelerator for innovation. The numerous sub-programs i.e., Eco-Logo[4], the Build Green Program, Tree Plan Canada, the Healthy House and the Advanced Houses Programs etc., are all changing how the traditional diffusion process functions. They can now be more fully integrated so that the follow-through phases of these demonstration programs can capitalize on this context for concerted action and further acceleration.

The implementation of the "information highway" will provide high speed transfer of texts, diagrams and videos for product description and training purposes. The role provincial building Centres can assume in the acceleration process needs to be quantified in relation to the potential this advanced communications system provides. The benefits of high speed (satellite and fiber optic cable) communications with the members of the International Union of Building Centres also needs to be assessed for its potential to more efficiently present Canadian products and techniques to external markets linked to sustainable housing.[5]

Late note: *Footnote 5 is significant. Information overload is real. Most people are unaware of house demonstration programs; many don't know R2000. Let's not get "carried away" by the potential of electronic communication tools. Emphasis should be on increasing quality of information, improving distribution, and reducing quantity.*

7.0 THE INNOVATION PROCESS

7.1 Established Industries

The strategy for innovation in larger established companies is necessarily different than in smaller companies. Larger companies are more cautious about introducing new products and technologies. There are good reasons for caution, big companies can make big mistakes. There are also poor reasons for non-innovation: resistance to change being a major problem (complacent and comfortable employees often wish to maintain status quo).

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[4] The Eco-Logo program started with good intentions but appears to have become a marketing tool.

[5] Although we have computer based telecommunicative tools they are not easily adopted by the contracting part of the building industry. Our feeling is that Ottawa based opinions of the success of computer based information networks, appear to be more positive than the Canadian norm.

Important characteristics of innovation in larger established companies are:

- Building product margins are insufficient to accept high risk of product/technology failure, and shareholders expect asset protection and security. Internal company criteria for acceptance of brand new innovations are set very high, based upon the potential for costly mistakes with new uses of new products. [New uses of existing products and existing uses of new products are far more acceptable].
- Large companies have large investments in existing people skills, existing manufacturing operations and existing distribution/sales networks.
- Existing companies look for products which can be made with existing (or economically modified) production facilities and/or be sold through existing distribution channels. New product introductions are rationalized by the synergy with either manufacturing or distribution.
- The more innovative large companies breed internal "Champions" for product innovations, and protect these champions from bureaucracy and jealous colleagues.
- Champions are generally well accepted by marketing/sales parts of companies (they are seen to bring greater sales volumes and margins) and less well accepted by production people (they are seen to bring headaches).
- New products made elsewhere are easily accepted. New products made in-house can meet strong resistance.
- Once senior managers (divisional general manager level or higher) support a project, innovation is fast-tracked. One problem for R&D is that internal funding is often inadequate in early stages of innovation when time is available, but time is inadequate in later stages of development when funding is available.
- Managers with flexibility and depth of experience are most useful. Generally the product/innovation champion remains in place and is supported by these people and their staff. Emphasis is placed on financial targets and strategical advantages, with a view to winning approval from the company Chairman and Board of Directors.

Product and technology development in larger established companies can be described as a "Cautious walk": generating a new product for an existing use, finding that the new product has a wider range of use, adding distribution to service the new use, and then adding other products to service this added distribution channel.

7.2 Entrepreneurial Companies

The innovation process for individual inventors or small investor groups supporting a new product is financially daunting, on the other hand the innovation process is more natural and less hindered than in large companies.

Individuals and small groups usually underestimate the time and expense of meeting all the product approvals and are often overwhelmed by the cost and time of the process. To some extent this is because they are always more optimistic about the performance of their innovations than regulators and future customers.

Ten years ago major corporations were very uncomfortable with innovation and, although large corporations have spent major effort in the last decade to streamline operations, they are still uneasy with the innovation process. [Ref 7.1]

The next section describes the product approvals process, and provides a flow chart for Canadian & U.S. product approvals for building envelope related products. This section demonstrates the complexity of product approvals in a simple form. We hope that it will be useful for would-be innovators.

7.3 Product Approvals Process

7.3.1 Legal Requirements

Building regulations are the authority of local government. Most local governments adopt model codes with minor modifications.

Model codes do not approve products as such but require that products be fit for purpose. For example the 1990 Ontario Building Code states:

> *"All materials installed to meet the requirements of this Code shall possess the necessary characteristics to perform their intended functions when installed in a building".*

The responsibility to ensure that a product is fit for purpose rests with the specifier.

Many sections of building codes require products to conform to standard specifications, and require building systems to meet certain performance requirements (eg. in standard fire resistance tests). Where such mention is made, compliance with the relevant product standard becomes a legal obligation.

Product standards usually do not exist for entirely new products, and it is important to obtain evaluation reports from authorities which will be acknowledged by building code officials. Some building code authorities have their own building material evaluation commissions, but most rely on outside agencies.

The mechanism for new product approval in Canada is to obtain a Product Evaluation Report from the Canadian Construction Materials Centre (CCMC), a section of the National Research Council. CCMC reports are accepted by provincial building code authorities,

building inspectors and home builders.

It is important to work closely with the assigned CCMC evaluation officer to ensure that testing requirements are both proper and reasonable. [The Canadian system roughly parallels the Agrement system in Europe].

US building codes are not as regimented as in Canada. Product liability concerns are left to the courts. There is no government organized approval system for new products and it is easier for new products to enter the marketplace in the US.

The US Federal Trade Commission has requirements about fair advertising and requires that product performance be fairly represented. In some instances, such as with insulation product R-values, the FTC specifies evaluation procedures.

7.3.2 Other Requirements

Building designers and product specifiers rely heavily upon manufacturer information about product compliance, with recognized standard material specifications, and the performance of products in building envelopes (eg. walls and roofs). For example, Factory Mutual or Underwriters' Laboratories fire rated systems are commonly specified.

In Canada, for a new product which does not fall within the scope of an existing standard, a CCMC report would substitute for product compliance with a recognized standard. In the US, one approach would be to evaluate the new product against the most relevant (closest) existing standard specification of competitive products.

ASTM, CGSB, CSA and other product standards contain limited fire resistance requirements. To market effectively against competitive products, fire resistance performance of common building systems and products are often required. In this area insurance underwriters laboratories (Factory Mutual & Underwriters' Laboratories) provide systems testing, product approval and labelling services.

Underwriters require production samples which have been manufactured with full quality control to be tested in order to provide product approvals. For small entrepreneurs this requirement is difficult, if not impossible to meet because they rarely have access to suitable production facilities. One option is to undertake developmental, or indicative tests with these agencies. Although approvals will not be granted, good results in indicative tests are sometimes accepted for initial sales (enlightened government agencies could help in this area).

Sound transmission classifications of various wall and ceiling systems, and noise reduction coefficients of the product may also be required.

Systems testing is expensive and is commonly shared by suppliers of component products used in the system. For a new product this process is expensive and it is wise to be selective about the initial fire rated systems tested.

In some areas of the building industry, national and local associations have specific approvals processes for products. This is more common in Canada where contractor associations often provide system warranties. An inventor needs to be aware of such approvals and limitations. This can be a significant barrier, eg. in Alberta, the provincial roofing contractor association requires that new products be used for two years prior to acceptance in their roof warranty program. [This has proven to successful in "weeding out" problems which have occurred on roofs elsewhere. What is required by the Alberta Roofing Contractor Association is in the "mind set" of most builders].

Some agencies, such as Canada Mortgage & Housing Corporation, have programs to accelerate the introduction of environmentally attractive products. Although not "approvals" as such, CMHC technical bulletins might be useful to the marketing part of the innovation/approvals process.

The next section provides flow charts for Canadian and US product approvals, with typical time-frames for approvals.

7.3.3 Canadian & US Product Approvals Flow Chart

Acronyms used:

ASTM - American Society of Testing & Materials
BMEC - Building Material Evaluation Commission
CCMC - Canadian Construction Materials Centre
CGSB - Canadian General Standards Board
CSA - Canadian Standards Association
FM - Factory Mutual Research Corporation
ATL - Approved Testing Laboratory (eg. Ortech)
UL - Underwriters' Laboratories Inc.
ULC - Underwriters' Laboratories of Canada

ACTIVITY		MONTH					
CCMC 1.	Determine CCMC product evaluation requirements.	X					
CCMC 2.	Ensure provincial BMECs will accept CCMC requirements.	X					
CCMC 3.	Schedule ULC and ATL testing.	X					
CCMC 4.	Produce material with ULC (or UL) witness, and ship material to testing laboratories.		X				
CCMC 5.	Completion of ULC and ATL testing.				X		
CCMC 6.	Address any out-of-spec results.				X		
CCMC 7.	Forward ULC and ATL test reports/letters to CCMC.					X	
CCMC 8.	Obtain CCMC evaluation report.						X
BMEC 1.	Obtain provincial BMEC evaluation reports.						X
ASTM 1.	Evaluate product against most relevant US (ASTM or other) product standard.		X	X	X		
CSA/CGSB 1.	Evaluate material against most relevant Canadian product standard (if not already required by CCMC).		X	X	X		

7.3.3 Canadian & US Product Approvals Flow Chart..continued

ACTIVITY		MONTH					
FM,UL,ULC 1.	Define systems tests required for marketing.	X					
FM,UL,ULC 2.	Schedule testing at FM, UL & ULC. Coordinate testing and use engineering calculations to reduce UL & ULC costs.	X					
FM,UL,ULC 3.	See step CCMC 4.		X				
FM,UL,ULC 4.	Address any out-of-spec-results.				X		
FM,UL,ULC 5.	Obtain FM, UL & ULC test reports/letters.					X	
Others 1.	Evaluate product against critical US Federal specifications (eg. Federal Trade Commission).		X	X			
Others 2.	Define other test information useful for marketing, eg. noise reduction coefficient of the material and sound transmission classification of selected wall and ceiling systems. Undertake testing as necessary.	X		X			
Others 3.	Contact major user associations (eg. US and Canadian Home Builders' Associations) to identify any special local-chapter requirements.	X					

7.4 Regulatory Sector's Role in Impeding Innovation

One of the authors has had first-hand experience with National and International Standards Writing Organizations for almost 20 years. Concensus standards are difficult to develop and the work is frustratingly slow. In most cases this slowness is based upon the careful resolution of valid technical concerns.

There are, however, some standards which do not withstand technical inspection and are sorely in need of change, but changes are prevented by special interest groups. In this regard, some Canadian Standards Writing Organizations must shoulder some of the blame.

One example of resistance to change follows:

- In 1976 Dr. Mark Bomberg of NRCC requested that the procedure for determining R-values of plastic thermal resistance be reviewed by CGSB. Specifically the validity of using high temperature pre-conditioning of cellular plastic foams was questioned, as was the logic of having three different test conditions for three insulation materials with similar uses.
- This subject was discussed, with no action, by CGSB committees on an annual basis for a decade.
- In 1987 and 1989 two expert task groups established by CGSB supported the need to change the procedures used to evaluate R-values, as they misrepresented the actual R-values of many materials.
- In 1989 changes to the standards were opposed by two manufacturers for unstated technical reasons.
- The situation today is that we have four different test procedures to measure R-values for plastic foam insulations. One new product standard was written, and a brand new procedure with no high temperature conditioning was adopted.
- Each plastic foam insulation material used in Canada today has a specific and different pre-conditioning procedure for R-value measurement. Most products yield four different R-values depending upon the procedure used.
- Representatives from some companies with more favourable test conditions have repeatedly resisted change. This resistance is not based upon the idea that CGSB standards are technically sound, but on the promise that a new test will be available and accepted by all in one year's time. This argument was used to oppose standard changes in 1978, 1987, 1989, 1990, 1991, 1992, 1993 & 1994.
- A decade ago, in apparent frustration with this process CMHC, and later CCMC, adopted maximum R-value levels for certain insulation products. This was technically responsible (as CGSB procedures over-estimated R-values) but this opportunity does not exist for private industry innovators, who face "non-level playing fields".
- In 1992, one of the authors, in collaboration with NRCC and PWC, founded the Canadian Coordinating Committee on Thermal

Insulation Standards and Quality. Eighteen members of this committee provide a widely representative industry group, including all CGSB standards writing committee chairmen. Our goal is to improve the quality of standards and the standards writing process for thermal insulations in Canada.
- Meanwhile building designers and code writers base heat loss calculations and new energy codes on inappropriate standards.

8.0 RECOMMENDATIONS

At the conceptual stage of this project, it was envisaged that performance and cost information from recent demonstration houses would have been available, and that this project would have evaluated options for increasing the acceptance of environmentally sustainable high performance housing with respect to economic, technological and industry readiness aspects.

Unfortunately, the performance and cost information from recent demonstration houses is not yet available.

8.1 Accelerated Use of Environmentally Responsible Products

Widespread acceptance of environmentally sustainable high performance housing will not occur without concurrent economic attraction.

Simple 10 year paybacks (eg. saving $700 annually from a $7,000 GSHP) are not attractive to average homeowners unless financing and performance (including maintenance and repair) risks are underwritten. If such risks were underwritten, strong environmental and economic motivation would exist and widespread acceptance would result from effective information/marketing.

Prior to making a purchase decision most Canadian homeowners ask:

a. Why do I want it?
b. Can I afford it?
c. Does it work?
d. Is there a better way (to accomplish the objective).

The answers which result in positive purchase decisions are:

a. For increased comfort and/or savings
b. Yes
c. Yes
d. No

Other combinations of answers usually result in a non-purchase decision. This may appear simplistic, but it provides the basis for general ways to accelerate the use of environmental housing innovations.

a: Why do I want it?

The environmental factor is important but increased comfort and/or savings are required. Accurate, reliable and persuasive performance information is required for products. This is available in limited supply and over limited time-frames for new innovations. **Acceptance would be accelerated if performance warranties were given. (Recommendation 1).**

b: Can I afford it?

Most Canadian's purchase homes through mortgages. Few would purchase homes if such financing was unavailable. (Rather than asking why environmentally sustainable high performance housing products are not being bought, we might have been asking why houses were not being bought). **Suppliers of products should be willing to stand behind their products, not only with performance warranties but with financing. If this were done, widespread acceptance would likely result. (Recommendation 2).**

c & d: Does it work? Is there a better way?

Third party documentation about product performance, and alternative ways to accomplish the homeowners' goals could prevent confusion and indecision regarding purchases. Such documentation should be accurate, short and clear. **Case studies of homeowner decisions for typical houses eg. heating & ventilation options for suburban houses built to the 1975 building code, would be most useful. Agencies such as CMHC would be the most credible sources of such information. (Recommendation 3).**

Any move to reduce costs by product manufacturers is desirable. Most actions are within the control of the manufacturers, however, product certification costs are high and can be reduced. The use of CANMET HOT 2000, ENERPASS and VISION 3 computer programs for simulating heat loss and window performance are useful in this regard. CSA's acceptance of simulated U-values and solar heat gain coefficients for windows has significant cost reduction potential.

CSA's acceptance is based upon good correlation of computer simulated results with many test results. Establishing the correlation base was expensive, but future product development and product acceptance for windows will now be faster and less expensive. The computer simulated performance approach to product acceptance by code and standards bodies has attraction in other areas (particularly for mechanical systems). **One role of manufacturer associations could be to develop computer models which simulate product performance and which will be acceptable to code and standards bodies. Organizations such as CCMC would be a useful resource in this area. (Recommendation 4).**

Reduction in costs are important to individual or small businesses involved in product development, but sourcing of sufficient R&D funds is usually more important.

Often large building material and hardware distribution groups are searching for environment-related innovative products that will enhance their image with existing clients and attract new customers to their stores. **Alliances between innovators and distribution groups can significantly reduce market entry costs and accelerate the diffusion process for the product or technique. There appears to be a role for CMHC & NRCC in establishing such alliance, perhaps through IRAP. (Recommendation 5).**

8.2 Accelerated Implementation of Environmentally Responsible Infrastructure

The prime motivators for municipalities are financial and political. Municipalities are being squeezed by rate payers on the one side and higher levels of government on the other. Municipal officials are required to be primarily economically prudent, and secondarily environmentally responsible. In some areas, economic and environmental effectiveness are seen to coincide (Blue boxes), in most other areas economic and environmental effectiveness coincide, but they are not generally perceived in this way. This lack of understanding is often due to:

a. Insufficient or misleading information.
b. Differing time frames (short financial/political v. long financial/environmental).
c. Inflexibility (maintaining status quo, ignorance and laziness).

a: **Accurate and authoritative information, eg. about water quality, is required. This should be simple, clear and ideally short. Agencies such as CMHC could be credible sources of such information. (Recommendation 6).**

b: **Allocation (or withholding) of funds to municipalities for environmental issues is a strong influencer. Provincial governments have a key role here. CMHC might reject financing for houses where municipalities are not environmentally responsible. (Recommendation 7).**

c: Voters will replace local officials if they perceive that quality of life is being negatively influenced by them.

In the area of energy and water efficient landscaping; continuous improvements in computer-aided territory management techniques are providing efficient tools for urban administrators to implement environmental innovations and improve their monitoring capacities. The integration of topographical maps, satellite photography and aerial "videography" (the use of high performance video fly-overs

for detailed monitoring), now enables planners and regulators to maintain efficient and easily up-dated information bases.

Using these types of tools, strategic bands of coniferous and deciduous trees can be systematically planted to reduce wind speeds, noise, dust, run off, etc. for entire developments. Solar zoning considerations can also be anticipated, thus facilitating the formulation of appropriation regulation for preserving access rights.

A conference on the use of such tools, primarily aimed at local municipal officials, would be useful for technology transfer. Sponsorship by CMHC and Provincial Housing and/or Environment Ministries would be appropriate. (Recommendation 8).

Off-grid experimental, special zoning areas could be created for the mass demonstration of innovations such as those in the Codicil Healthy House. This option could prove to be cost effective for municipalities with areas of bed rock close to the surface and problem soils. This subject might be an interesting topic for the abovementioned conference, as would be the use of computer data bases for inter-municipal communications on environmental projects.

Almost half of our survey respondents said that a national critical path was necessary or desirable to accelerate implementation of environmentally sustainable high performance housing. A critical path combining the resources of CMHC, CANMET, CHBA, utilities, the regulatory sector, municipalities, NGO's, etc., would certainly be able to reduce the traditionally slow diffusion rate for innovations within the building industry and in the marketplace. It would also prioritize job creation around the export markets for viable Canadian building products and know-how.

There is already a critical path taking place in rudimentary form by the established links between stakeholders in the demand side management arena. However, contributions could be made by other sectors if a mechanism for interaction were created to assure their participation.

Such coordination should focus on a particular issue, eg. tree planting. Task forces should set clear objectives and completion dates. Disband (sunset) dates are effective against interminable committees.

We recommend that CMHC create a task force involving the Federation of Canadian Municipalities, CHBA, Canadian Urban Planners, Tree Plan Canada etc. and discuss possible co-sponsorship of a comprehensive tree planting guide that will assure the proper siting of trees being planted and the preservation of existing mature trees for developments in forested areas. (Recommendation 9).

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APPENDIX A: QUESTIONNAIRE

Introduction:

Hansed Booth Inc, in collaboration with Peter Kettenbeil, is undertaking a research project to identify opportunities for accelerating the implementation of environmentally sustainable high performance housing.

The research methodology has been to select ten innovations recently demonstrated in the CMHC Healthy Houses Competition, the CANMET Advanced Houses Demonstration Program, and similar projects. The next steps are to identify the opportunities for implementing of these innovations into everyday use, and the obstacles which lie in the way of their implementation.

Innovation	Principle Reasons for Selection
1. GSHP/HRV/DHW configurations.	Significant non-renewable energy savings, healthy indoor air, multipurpose HVAC/HRV/DHW uses, good retrofit potential.
2. High efficiency gas DHW/heat exchanger/HRV	Significant non-renewable energy savings, healthy indoor air, dual purpose DHW/heating, low cost fuel, good retrofit potential.
3. Contraflow fireplace.	Use of renewable energy source for heating, clean burning, low cost and good retrofit potential in semi-rural areas.
4. Super efficient windows	Significant fuel savings, "free" solar energy source, synergy with HRV and heat pumps for space or DHW heating use.
5. Engineered timber frames.	Increased use of engineered wood products and a complete rethink of timber framing is indicated.
6. Recycled polyester fibrous insulation.	Interesting entrepreneurial project where innovator has "lived" 5 years of experience of opportunities and hurdles regarding implementation of innovation.
7. Water conservation	Good example of resource management where one area impacts on many others for a major short and long term contribution.
8. Water purification	Timely issue, great importance to long term health, excellent potential benefit/cost ratio.
9.Comprehensive landscape	Reduces $C0_2$, increased energy efficiency, local air quality, water use reduction
10.Indoor Plants	Reduces indoor air pollutants, low cost solution, quality of life attributes

These ten innovations are, in our view, likely to affect the environment very significantly. The selection process was somewhat subjective, and we understand that other experienced building experts may have chosen different innovations.

The actual innovations are, however, secondary to the identification of opportunities and obstacles regarding their implementation. The innovations selected are vehicles by which we can focus upon, and better understand, the commercialization process: ultimately we wish to identify ways to capitalize on the opportunities and overcome the obstacles.

You have significant experience which impacts innovations and their commercialization. We hope that you will take ten minutes from your busy schedule to answer eight questions.

We would also appreciate comments that you might have about the implementation of environmental innovations in our industry, and ways to accelerate this.

Questions:

1. What are the three most important opportunities that you foresee for accelerating the introduction of these, or other innovations at a faster pace? Please list in order of priority.

2. Based on your experience, what are the three most important obstacles facing the acceleration of introduction of these innovations into everyday use within our industry? Again please list in order of priority.

3. What are other relevant factors impacting building innovation and environmental housing?

4. Have you been following the evolution of the R-2000, Healthy Housing and Advanced Houses Program?.

5. Do you feel that there has been sufficient information circulated to your particular section of the building industry concerning the recent innovations demonstrated in these programs?

   If yes, why? If no, why?

6. Do you have any comments on the innovations selected?

   a. Do you think they are innovative and will benefit the environment in a major way?
   b. Are there other innovations which you would have selected? Please feel free to replace any of the ten innovations with ones of your choice. Why do you prefer your innovations?

7. Is a national critical path for the acceleration of these environment related innovations feasible? If so, what key elements can you recommend for its content and realization?

8. May we mention your name as a contributor to our research?

9. Other comments?

APPENDIX B: QUESTIONNAIRE RESPONDENTS

Name	Expertise/Background
Warren Arseneau E2D Development Corporation Burlington, Ontario	Entrepreneurial developer of recycled polyester fibrous insulation.
Gerard Caron President Vert Mark	Market realities for Alternative Grass v. Sod
John Carroll Carroll Homes Ltd. Saskatoon, Saskatchewan	Innovative Builder
Jean-Louis Cayer Technology Marketing Manager CRIQ Ste-Foy, Quebec	Industrial development of technologies
Bill Dawson Descon Inc. Ottawa, Ontario	Former CEO, CCIS Database Server Experiment & Obstacles to Innovation, Canadian Construction Information Services
Colin Davidson University of Montreal Int'l Building Centre Project Montreal Quebec	Industrialized Components - Housing, Profile of UCIB
Andre Fauteaux Founder of Newsletter House of the 21st. Century Newsletter St. Donat, Quebec	Communications Related Opportunities & Obstacles
Yves Lacroix Director General City of Mirabel Mirabel, Quebec	Tax-Infrastructure Cost Benefit for Quebec Municipalities Prof. Municipal Fiscal Planning Ecole Polytechnique
Tom Lawland Brace Research Institute McGill University St. Anne de Bellevue, Quebec	University-Industry Liaison, Opportunities & Obstacles for Solar
Joe Lstiburek Building Engineering Corp. Boston, Massachusetts	Innovative Building Engineer
Gillian MacLeod Ontario Hydro	

Toronto, Ontario	Senior technical advisor - environment
Cam McNeil CANMET Ottawa, Ontario	GHSP Expert ex. Chinook Phi-Beta Corp.
Jacques Mercier Hydro Quebec Montreal, Quebec	Advisor to Vice President on Energy Efficiency
Richard Miller Clayton Developments Ltd. Halifax, Nova Scotia	Innovative Builder
Lewis Nakatsui Lincolnberg Homes Ltd. Edmonton, Alberta	Innovative Builder
Jan Oosterwaal Domtar Construction Materials Montreal, Quebec	Development/Manufacturing/Sale of Large Building Materials
Benoit Perron University of Quebec Montreal, Quebec	650 pp. Masters Thesis on Energy Efficiency
Frank Quinn National Business Manager Alcan Building Materials Toronto, Ontario	Development/Manufacturing/Large Volume Building Materials
Nigel Ravenscroft Research Manager Dow Chemical Granville, Ohio	Development/Manufacturing/Large Volume Building Materials
Ron Zalum Industrial Technology Section Environment Canada Montreal, Quebec	Opportunities & Obstacles for Innovative Sewage Treatment Systems

APPENDIX C: LIST OF PERSONS INTERVIEWED FOR FINAL REVIEW

Warren Arseneau
President, E2D Development Corporation
Burlington, Ontario

Jacques Brisson
Quebec Coordinator, Tree Plan Canada
Quebec, Quebec

Bertrand Dumont
Editor, Quebec Vert
Montreal, Quebec

Richard Kerr
President, Sunworks Inc.
Hawkesbury, Ontario

Denis Michel Ladoux
President, AquaLandis Inc.
Montreal, Quebec

Andre Limoges
Director General, Société de Reverdissement
Montreal, Quebec

Gillian McLoed
Senior Technical Advisor - Environment
Ontario Hydro
Toronto, Ontario

Cam McNeil
Program Manager, CANMET
Ottawa, Ontario

Peter Scott Smith
President, Panteen Associates
Ottawa, Ontario

Robert Valdmanis
Senior Counsel, Public Affairs
Robin Palin Public Relations Inc.
(Public Relations Firm for CWDMA)

Tom Whicher
Manager, Sheriden Nurseries
Dorion, Quebec