CMHC HEALTHY HOME

TORONTO, ONTARIO

MARTIN LIEFHEBBER ARCHITECT INC.

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QUICK FACTS

Building Name	CMHC's Healthy House
City	Toronto, Ontario, Canada
Year of Construction	1996
Major Partners	CMHC, The City of Toronto Public Health, Ontario Ministry of Health, Ontario Ministry of Environment and Energy, Ontario Hydro's Environment and Sustainable Development Division, Toronto Hydro
Architect	Martin Liefhebber
Consultants	Read Jones Christoffersen Ltd., Engineers, Ontario Hydro, RAL Engineering Ltd., Creative Communities Research Inc., Waterloo Biofilter Systems Inc., Blue Heron Environmental Technology, Urban Entomology Lab at University of Toronto
Program	A semi-detached private home for a family of four
Gross Area	1,700 sq ft
Climate	Southern Ontario Climate: Temperate-Cold
Special Features	Designed to function independently of the infrastructural grid, relying on passive solar gain for heating, natural ventilation and shading devices for cooling, rainwater collection for its water supply, and photovoltaic panels for its electricity
Special Site Conditions	Municipal sewage system not available; narrow constrained lot
Aesthetics	Typical, narrow infill home with photovoltaic array sun-shading dominating the front elevation
Structural System	Durisol concrete masonry load bearing walls with reinforced concrete floor slabs and steel roof structure
Special Construction	Cistern beneath backyard deck connected to filtration system that collects rain and grey water for "recycling" and reuse within the house
Day-lighting	South facing glazing
Thermal Conductivity	Concrete as thermal mass
Ventilation	Natural ventilation through operable windows and the stack effect
LEED Rating	See LEED Home considerations, page 11
Cost of Construction	Approximately $500,000 for 2 units

INTRODUCTION

Statistics show that in today's society, most people spend the majority of their time indoors. For the typical Canadian, approximately 90% of their time is spent inside, much of which is spent in the home.[1] For this reason, a healthy indoor environment is paramount in providing good living conditions, improving social well-being, and promoting individual health. Because so much time is spent within the home, housing is also a major consumer of energy and resources, while also being a major generator of waste both during construction and after occupancy. For these reasons alone, it becomes increasingly important to maximize our resources and promote energy efficiency in housing.

In June, 1991, the Canadian Mortgage and Housing Corporation (CMHC) hosted a competition in search of a home design that would be exemplary in its reduced resource and energy consumption. The competition was to demonstrate to the public and housing industry a means of achieving a balance between the occupants' health, energy and resource efficiency, environmental responsibility and affordability. As an added requirement to the competition brief, the winning house design was also to be able to work independently from the infrastructural grid and be self-sufficient, even on a site where city services were available.

In February 1992, two winning entries were announced, one in Vancouver and one in Toronto. The Toronto-winning entry, designed by architect Martin Liefhebber, is a 1,700 square-foot semi-detached house which includes three bedrooms and a home office. Liefhebber's design for a "Healthy Home" has since become synonymous with energy and resource efficiency, and also quality of indoor environment.

Figure 1 (Right): The CMHC Healthy Home is one of two townhouse units in Toronto.

Figures 2 and 3: The CMHC Healthy Home was constructed as an infill project within the typical urban residential area of Riverside, within an otherwise typical streetscape.

SITE

The Toronto CMHC Healthy Home was constructed on a vacant infill lot in Riverdale, a community in north-east Toronto which aspires to enhance the quality of life and economic prosperity of its residents while promoting stewardship of the local environment. The building site was chose for its central location and proximity to existing public transportation lines. With an area of only 132 square metres (6 metres wide by 22 metres deep), the site is considered small even in comparison to the standard urban infill lot in central Toronto.[2]

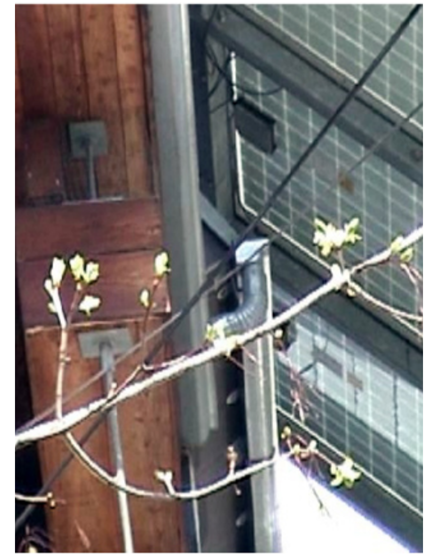
Since the house is self-sufficient and independent of the infrastructural grid – in part by programme and in part by necessity since the site has never had sewer service – the landscaping requirement was kept to a minimum, while being both functional and aesthetically pleasing. The front yard of the house is planted with perennials and edible fauna. Two patios were built onto the house – one in the front and one at the back. The patio at the rear of the house was constructed as both amenity and to collect and divert surface and rainwater into a cistern located beneath it. The rear of the site posed a problem because adjacent homes are located on a steep slope, making the backyard small and enclosed. As such, the backyard has its own particular microclimate and light levels, making plant selection for the rear of the house difficult.

SUSTAINABLE DESIGN STRATEGIES

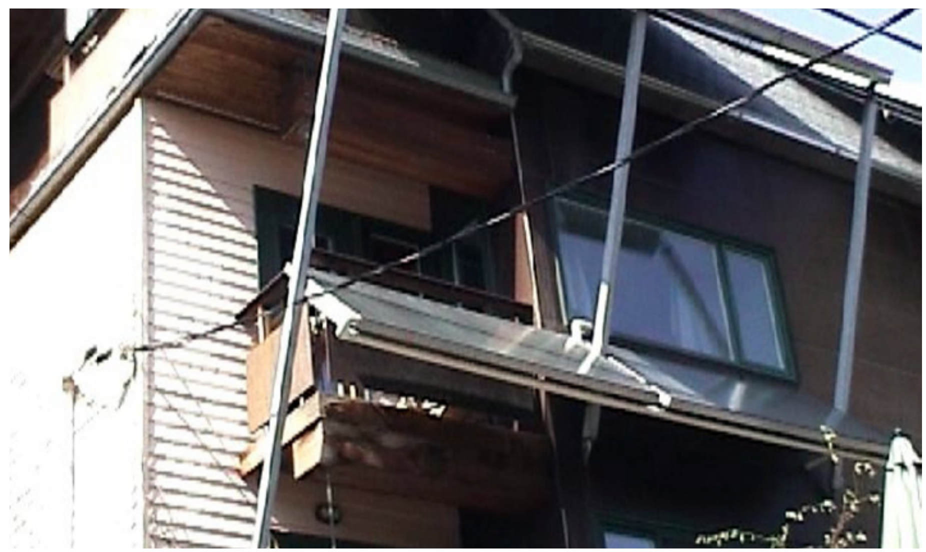
The CMHC Healthy House project is a product of high achievement in housing design, landscaping and technology. In order to maximize the efficient use of resources without sacrificing the occupants' lifestyle, functions of the residence were carefully examined to find compatible programmatic elements that were also reciprocally beneficial in terms of energy and resource efficiency without compromising the functionality of spaces. In order to maximize the gains from these function-efficiency interrelationships, the house employs systems of both advanced technology and natural passive means for heating, cooling, lighting, potable water conditioning, and effluent treatment.

One of the principle sustainable design strategies used in the Healthy House is passive solar systems. Passive solar energy is harnessed in two ways: for electricity and heating. In terms of electrical supply, although the passive solar system adds, on average, 20% more to the overall building cost in comparison to a traditional electrical hook-up to the infrastructural grid, this system not only saves on operational costs, but can also reverse supply the grid with its excess energy. When functioning properly, a two way-metering system is used to monitor the electricity stored with the utility.

The CMHC Healthy House relies on two 3 kilowatt photovoltaic (PV) arrays, consisting of eight 285 watt panels for its power.[3] The arrangement of these panels on the upper storey of the house, angled due south at 45 degrees, allows them to act as a shading device for the walls and windows of the third floor during summer. The photovoltaic array is fed into a localized panel comprised of voltage regulators, a disconnect switch and a Trace 4kW inverter to convert 48 VDC to 12 VAC.[4] The conversion technology ensures that energy is available in any form when needed year-round. All of these components are tied to twenty-four 2 Volt gel batteries that can provide up to four days of power storage. However, as an added precaution, one of the PV arrays is entirely independent of the electrical grid. A second safeguard was also added in the case of an extra-long spell of overcast weather, consisting of a 4kW ethanol fuelled co-generation system providing back-up heat and power.[5]



Figures 4, 5 and 6: Details of the photovoltaic panels that shade both the exterior balconies and south facade of the building from excess solar gain in the summer.



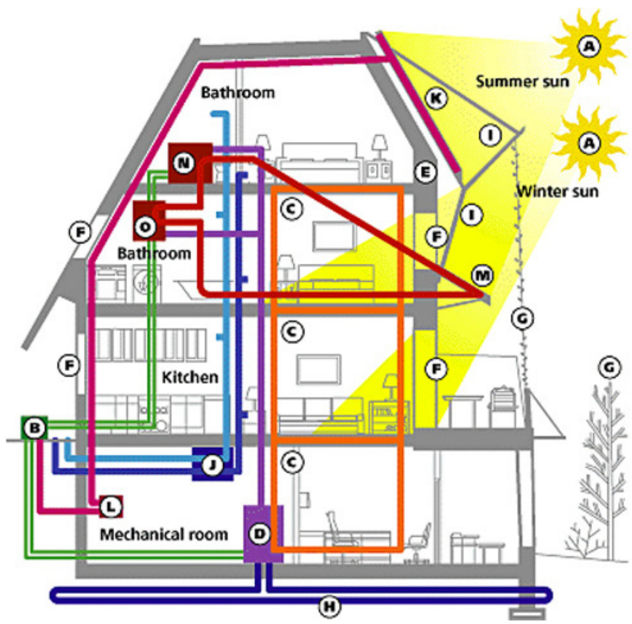


Figure 7: Passive Heating and Cooling and Photovoltaic Electrical Schematics

Water Heating System
A – Sun
B – Co-generator unit
D – Thermal Storage tank
M – Solar thermal panels
N – Reclaimed hot water tank
O – Drinkable water tank

Cooling System
C – Radiant solar floors
D – Thermal storage
E – Super insulated walls, floors & roof
F – Super efficient windows
G – Ivy Trellis and deciduous trees
H – Ground Loop
I – Shades

Heating System
A – Sun
B – Co- Generator unit
C – Radiant solar floors
D – Thermal Storage tank
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G – Ivy Trellis and deciduous trees

Electrical System
B – Co-generator unit
K – Solar photovoltaic panels
L - Batteries

The second way in which passive solar energy is exploited in the Healthy House is for day lighting and heating of indoor spaces. To take advantage of day lighting, south-facing glazing is maximized. During the summer, trees and ivy-covered trellises help control heat gain within the house through their shading effects. Conversely, due to their deciduous nature, when they lose their leaves in the fall, they also allow maximum light penetration into the house during the colder winter months.

In terms of heating, when comparing the CMHC Healthy House with a traditional dwelling, it uses about one tenth of the energy required to heat a conventional home.[6] During the winter, solar energy gained through sunlight penetration into the house, is retained in the concrete floor slabs during the day, and is released slowly at night through natural radiation. The sun also heats water which is circulated through pipes embedded in the concrete slabs which radiates from the floors into the house to supplement the heat which is gained through sunlight on the slabs. Any excess heat in the system is released into the earth surrounding the house. In order to reduce the energy needed to cool the building during the summer time, grey water heat-exchangers are used in lieu of a traditional air conditioning system because they produced less internal heat gain. As a result, this reduces the overall cooling load of the house, and accordingly, eliminates the need for any air conditioning at all.

The construction of the house also greatly contributes to its energy savings. This is true not only of the concrete used for the floor slabs that heats and cools the house, but also the airtight wall and roof construction, high levels of insulation and weather resistant materials. This is also true of the triple-glazed, thermally efficient windows that maximize solar gain and minimize heat loss during the winter months. With all these considerations put into the design of the house, the Home's heating bills were designed to tally at less than $80 per year.[7]

VENTILATION

Like its heating, ventilation of the Healthy House is based on natural systems. All rooms, including the storage room, are vented directly to the exterior through operable windows or fans. During the summer months, heat gain and humidity are controlled by a system of moderated airflow. This highly efficient system evenly distributes clean air throughout the house.

In terms of indoor air and environment quality, in addition to the highly effective ventilation system, finish materials such as paints were chosen for their low volatile organic compound (VOC) content to reduce any unpleasant odour, vapours, or potentially harmful off-gassing.

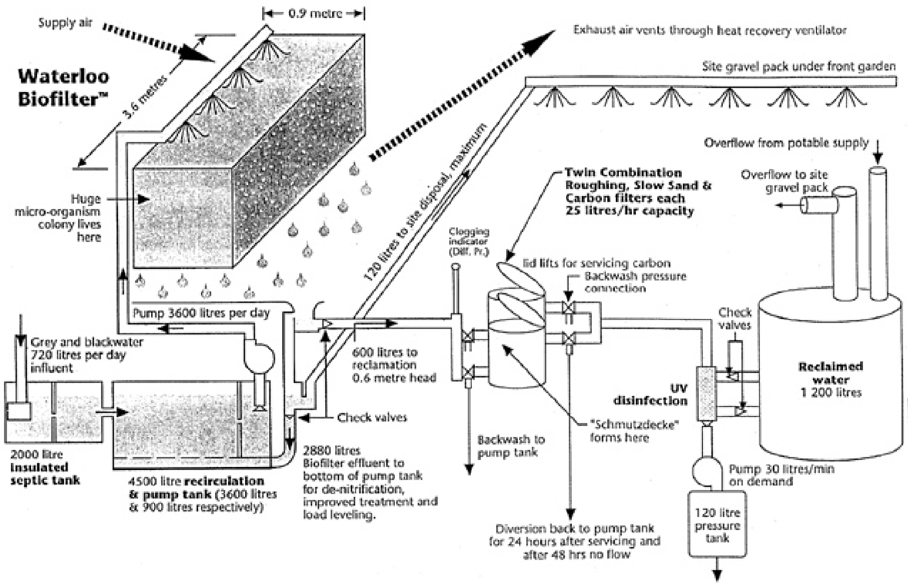
LIGHTING

The healthy house depends primarily on natural lighting. Large, energy-efficient, south-facing windows and skylights were used to maximize sunlight penetration into the house. Despite not needing artificial lighting during the day, at night the house uses an energy-efficient lighting system with compact fluorescents.

WATER

Since this house is a self-sufficient building, not only is it capable of providing its own power, but it is also capable of supplying its own water through the collection of rain/storm water. The Healthy House's water infrastructure supply depends on rainfall and recycled, or reclaimed water, from within the system proper. Through this system, the Healthy Home consumes approximately 1/10

Figure 8 (Above): Aside from operable windows, vents subtly located in soffits and along wall faces. Figure 9 (Below): Living spaces are filled with natural daylight.



of the water of a typical household. Approximately 80% of the water used in the home is achieved through this recycling. A typical household of a family of three consumes about 1,050 litres per day, or about 350 litres per person per day. In contrast, a family of three living in the Healthy House consumes only about 120 litres per day.[8]

The grey water in the house is treated through a purification system. The system is comprised of a three-step process. First, it passes through a Slow Sand Filter. Second, water passes through a tank of charcoal that absorbs any inorganic compounds. Third, the water is further disinfected by passing through a tank with ultraviolet lights. After going through this process, the water is safe to drink. Most importantly, however, the water is being filtered through a process that does not use a drop of chlorine, aluminum, or any other chemical additive.

Rain water is also treated and purified before it is used in the showers, washing machine, and toilets. The rainwater and snow melt are collected in an underground cistern. Once collected, the storm water goes through a bio-filter – an anaerobic system where organisms break down complex molecules into simpler compounds, devours and digests the waste. The rain water then passes through the three-step process of the Slow Sand Filter, the carbon filter, and the ultraviolet light.[9] Any excess clean water is used for irrigation of the fruit trees and flowers located in the front yard. As an added benefit, through the diversion of the rainwater and snow-melt into the cistern, the net storm water runoff for the site is zero.

Figure 10 (Top): Schmatic of rain and waste water filtration process. Figure 11 (Bottom Centre): UV disinfection unit. Figure 12 (Middle Centre): Biofilter Foam Bulk-Filled container. Figure 13 (Bottom Left): Reclaimed water tank.

This waste water system is relatively inexpensive when compared to the true-cost for a municipality to bring infrastructural services to a building site. In some rural or green-field areas, the cost is as high as $100,000 per dwelling.[10] In the Greater Toronto Area, however, the cost per dwelling is typically $8,000 for a waste water hook-up. The waste water systems used in the Healthy Home were approximately $15,000 per unit. Although, the Healthy Home system is nearly twice the cost of a conventional hook-up, the system is expected to slowly return on the initial investment by saving the amount of potable water consumed in the building because of its recycling and reclaim capacity.

In addition to its innovative waste water management, the Healthy House uses a secondary waste management strategy for its solid waste. This secondary system is comprised of two simple elements: an outdoor composter to accommodate for the household's organic waste, and built-in area for the collection and storage of recyclables.

ENERGY EFFICIENT APPLIANCES AND FIXTURES

In order to reduce energy use, a high efficiency hot water heating system is used to reduce fuel consumption. In the same vain, special home appliances and fixtures which use less water are also used. For example, a custom built refrigerator uses super-insulation which is five times more effective than urethane foam. The refrigerator motor and compressor are located outside of the house not only to improve efficiency in winter and reduce heat gain in the summer, but also to reduce internal noise levels for the indoor environment. Other energy-saving fixtures used include low-volume flush toilets, low-flow shower heads, and aerator faucets.

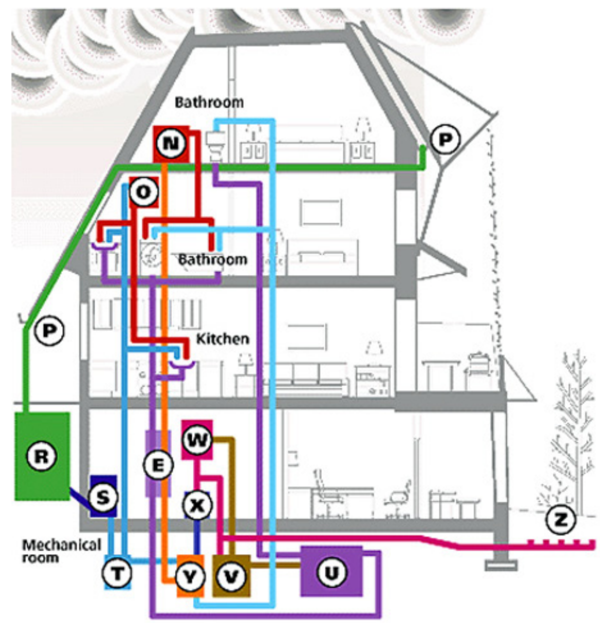
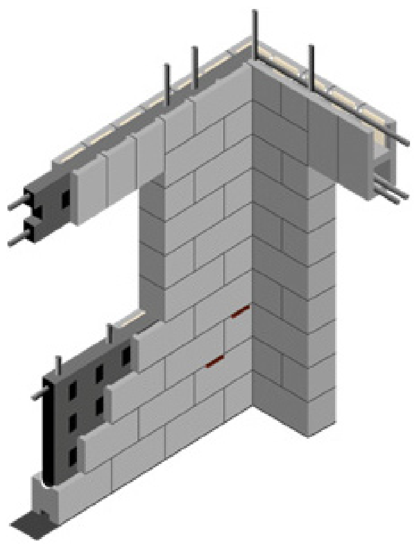


Figure 14: Water Collection and Filtration Schematic

Potable Water System
P – Eaves troughs
R – Rainwater cistern
S – Combination filter
T – Drinkable cold water tank
O – Drinkable hot water tank

Waste Water Management
E – Grey water heat exchanger
N – Reclaimed hot water tank
U – Septic tank
V – Recirculation tank
W – Waterloo Biofilter
X – Twin combination filters
Y – Reclaimed cold water tank
Z – Garden irrigation

Figure 15 (Top Left): Detail of wiring to photovoltaic panels. Figure 16 (Top Right): Kitchen counters are made in part from recycled glass. Figure 17 (Bottom Left): Glulam beam and column detail. Figure 18 (Bottom Right): Durisol wall assembly.



BUILDING MATERIALS

Building materials used in the healthy house are either reused materials from old buildings or readily available at reasonable costs, such as rapid-growing wood like spruce and maple. The house consists of 78% recycled, or natural, raw materials. The majority of these materials are locally produced, saving on transportation costs while also supporting the local economy.[11] The roof shingles are tiles made of old car bumpers, while the kitchen counter is made of recycled glass chips.[12] The house also uses "healthy" materials which are organic and emit few, if any, harmful vapours or VOCs, thus improving the indoor air quality. For example, cabinetry and shelving are made from formaldehyde-free woods and laminates.

All building materials and finishes are low maintenance and durable, such as the hardwood and tile used on the floors. Also, all materials such as wood, wallboard and fabrics were selected based on their effect on the indoor air quality, their overall embodied energy, and other relevant "environment costs." Not only was special consideration put into the interior finishes, but also the structure.

Special lightweight concrete blocks called 'Durisol'[13] were used as the structure, providing both a durable building, but also better insulation levels. "The Durisol wall forming system is a straight-forward method of building a reinforced concrete wall with built-in thermal, acoustical and fire protection. The wall forms are interlocking modular units that are dry-stacked (without mortar) and filled with concrete and reinforcing steel."[14] The Durisol system allows for customized levels of insulation for the wall assembly, while acting as load bearing elements of the structure.

COSTING

The house is designed in a flexible layout to reduce future renovation costs. By having an office at home allowing for residents to work from the house, it helps reduce energy consumption in a holistic manner by reducing fossil fuel consumption for transportation to and from an office. In spite of these savings, due to the off-grid, independent nature of this house, in terms of heating, water and hydro service, an additional $70,000 was spent on the specialized systems and materials that help the house achieve its energy efficiency. Also, because the Healthy House was part of a research project, approximately $13,500 was spent for project management and carrying costs during the six-month demonstration stage required by the CMHC.[15]

According to Rolf Paloheimo, owner of Creative Communities Research Inc. and also the developer responsible for its construction, about half a million dollars were spent building both units of the Riverdale complex, including the land costs.[16] Although the construction cost is quite high when compared with typical housing construction, it is offset by the low operation and maintenance costs. Just by being able to supply its own power, recycle its water, and being located on un-serviced land, it can provide a reasonable monetary return on the upfront capital investments made on its specialized systems, finishes and appliances. This is accomplished through its reduced annual expenditures which result from the 85% reduction in energy and water consumption, and waste conveyance costs.[17] However, with the owner's deal with the City to sell its excess power generated by its solar panels back to the infrastructural grid, in essence, the house earns money with its sustainable features. Paloheimo proudly claims, "We don't have a water bill, [and] we don't have a gas bill."[18]

Despite this, the photovoltaic system in the house added a significant premium

Figures 19 and 20: Backing against a steep slope, the north-facing rear yard is filled almost entire with a large deck that covers the rainwater collection cistern below.

to the cost of each unit. Typically, a solar electrical system with the photovoltaic panels that are not tied to the power grid cost approximately $35,000 more than a regular residential electrical system. The system also has four batteries that have a life span of only 15 years each, after which time they need to be replaced. For a PV system that is tied to the grid, an additional $20,000 premium is charged in addition to the upfront $35,000 up-charge. The Healthy Home system cost less than this $55,000 price tag because Ontario Hydro, as a sponsor of the Healthy Home project, put in a power conditioner which transforms solar DC power into power that can be used in the grid for only $500.[19] As a result of the conditioner, less expensive wire of a lighter gage was used throughout the house to help reduce the costs of the electrical system.

Figure 21: Landscaping in the front yard is kept to a minimum - no irrigation is needed. All planting and soft surfaces were chosen to mitigate storm water run off.

In the end, when compared with traditional residential construction methods and practices, the passive solar PV and water filtration systems added approximately 20% to overall building cost. Overall, the Healthy House cost about $120 per square foot. Ironically, according to Ken Fung at Chrisdale Homes, a Vancouver-based custom-home builder, this places the Healthy Home in the lower-end of the housing range.[20] In addition, the costs of the sustainable systems and materials used in the house can be recovered in 15 to 20 years of energy savings.[21] The estimated annual operating costs for both units of the Healthy House together is less than $300.[22] Thus, at the end of the costing exercise, the Healthy Home becomes a economical, practical, and healthy housing solution for Canadian families.

LEED HOME CONSIDERATIONS

When discussing sustainable design in architecture, the LEED "Green" Building Rating System, developed by the US Green Building Council (USGBC), is used as an industry standard as a means for quantifying how sustainable a building actually is. Although the rating system has come under much scrutiny for the rigour (and often arbitrary nature) in which it accredits points to a project, notwithstanding, it is a valuable tool for auditing a "green" building. The current rating system is geared toward new construction of commercial buildings; however, the USGBC is in the process of developing a comparable system for auditing residential construction.

Using the preliminary LEED-Home project checklist (version 1.5) as a guideline, the CMHC Healthy Home would score reasonably well in the eight categories of the system. Due to the level of thought and consideration integrated into every aspect of the Healthy Home, one would believe that it would score in the top range. This is not the case, however, due to the slanting of the rating system towards specific systems or products without weighting alternatives, such as passive heating and cooling strategies, accordingly. Hopefully, when the first release of the rating system is made public, it will account for the inherent contradictions to "best architectural practice." Despite this, an overview of CMHC Healthy Home in relation to the preliminary LEED-Home rating system is included below.

In the "Location and Linkages" category, which deals with aspects of site planning and selection beyond the individual owners' property lines, the Healthy Home respects its tenets that: avoid development of environmentally sensitive land; locate the building in close proximity to existing roads, power lines, green space, and mass transportation lines; and increase the local housing density to promote efficient land use. Similarly, in the "Sustainable Sites" category, the Healthy Home would score well despite its constrained site. The use of drought-tolerant plants and little turf, and innovative rainwater capture to irrigate landscaping and minimize erosion and site runoff, demonstrate the thought put into the site's design.

Ironically, the home would not score well in the "Water Efficiency" category, despite its innovative rain and grey water treatment system. The LEED-Home system attributes many points to very high efficiency plumbing fixtures, such as aerator faucets and low-flush toilets, in order to promote the reduction of potable water consumption. Although the Healthy Home does not consume an ounce of potable water from a traditional infrastructural hook-up because it recycles and reuses rain and grey water capture, it does not require high efficiency fixtures because the water is simply returned to the system to be reused. As such, the Healthy Home loses all points related to reducing potable water consumption. Unfortunately, unlike the LEED Commercial rating system, the LEED-Home system does not even incorporate credits for "innovative waste water technologies." As such, although it releases a mere fraction of the "black" waste water that a typical home would, the innovative water strategy integrated into the Healthy Home goes completely unrecognized.

In the "Indoor Environment Quality" category the Healthy Home gains few points because it does not have many of the monitoring systems (such as for CO_2 and radon) that the LEED-Home rating system requires. Likewise, although the every room in the house has direct venting to the exterior whether through fans or operable windows, because the Healthy Home does not have an air-conditioning system (an impressive feat for a home in Southern Ontario), nor forced-air heating, it does not gain points attributed to proper filtration. This is exemplary of the many contradictions in the LEED-Home rating system that seems to

Figure 22: "Light scoops" help bring natural light deep into the house, on all floors.

favour the consumption of technological products to reduce consumption of natural resources to achieve the same result as passive architectural solutions such as natural ventilation through operable windows. In other words, it seems as though active, mechanical solutions are still favoured over more traditional passive systems, despite the fact that the passive solutions consume fewer products and energy.

The Healthy Home gains a few points in the "Materials and Resources" category for its reduced floor area, promoting the efficient use of space. As for the other credits in this category, although careful consideration was given to building

Figure 23: Interior finishes are kept to a minimum, leaving all finishes exposed.

materials for their recycled content, it could not be determined whether the materials were locally manufactured and harvested, or if construction waste was diverted from landfill, thereby losing the other points in this category.

In terms of “Energy and Atmosphere” the Healthy Home scores exceptionally well. Due to the increased insulation levels and air-tight construction of the building envelope, the solar hot-water heating system, reliance on natural light, use of energy efficient light fixtures and appliances, and photovoltaic panels for power generation, the Healthy Home gains nearly all the points listed in this crucial category, save those listed for third-party verification and inspection of building construction and systems. Since this is the most heavily weighted area of the rating system, it boosts the overall performance of the Healthy Home.

In the two remaining categories, “Home Owner Awareness” and “Innovation and Design Process,” the Healthy Home performs well. It is in the latter category the home gains a few points for the innovative and passive strategies that went unrecognized by other credits. It is obvious that the Healthy Home exceeds many of the credit requirements, although in ways that almost contradict the rating system as it stands. Unfortunately, there are only four possible points for “innovation and design” whereas there are many more missed points.

Despite its shortcomings, the LEED-Home rating system is still a valuable tool when auditing more conventionally constructed homes that include air-conditioning and forced-air heating systems. It is only when the system is used to assess exceptional buildings that its flaws are revealed. Perhaps if more home owners and designers revert to more traditional passive systems that are integrated with “high-tech” solutions such as those integrated into the Healthy Home, these flaws can be worked out. In doing so, it will help create a more comprehensive and representative rating system, capable of fairly evaluating all sustainable design in home construction.

CONCLUSION

As technology improves and the population grows, due to mass media coverage and over-crowding of cities, people are becoming more aware of their health as it directly relates to their living environment. In order to enhance health and comfort, better indoor living environments are becoming necessary. By building more environmentally responsive housing that uses natural resources more efficiently and reduces the amount of waste being produced, simplified methods of heating and cooling such as passive solar systems and natural ventilation will become more prevalent, thereby reducing energy consumption by housing.

This will lead to better, less resource intensive living environments, and help improve occupants' health. Although, the cost of construction was comparably high to conventional residential units, when considered in terms of long term investment, eventually the Healthy House will pay for itself with its reduced operations costs. In fact, statistics have shown that the Healthy House will sell within the price range of other homes in the neighbourhood. Also, with our existing rapid improvement in technology, it will be possible for many of these sustainable features to be mass-accepted by the general population, thereby entering mainstream residential dwellings and reducing their costs for future developments.

There are many ways that we as a society can help achieve a more sustainable community that consumes fewer resources. For example, by providing opportunities for residents to work from home, it creates less dependency on vehicles and, therefore, generate less pollution from commuting. Also, by allowing for flexibility, and offering diverse and adaptable living spaces, we can reduce the cost of renovation and waste from construction. Other strategies for building sustainable communities include incorporating power generation into homes, such as PV panels, to help reduce peak demand for electrical energy. All of these things are demonstrated in the Healthy Home as a building block for creating more sustainable communities.

If this design knowledge can be more readily accepted, more efforts will be made to bring new technological developments into housing design and construction. The Healthy Home is but the first step in this chain of events. Although it represents a bold undertaking by the government and a private developer, the Healthy Home demonstrates the growing commitment of our society to creating not only sustainable buildings but also sustainable communities. For this reason alone, the Healthy Home is a success.

Figures 24: Detailed view of the CMHC Healthy Home's multiple south balconies.

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ACKNOWLEDGEMENTS

A special thanks to Christopher Ives for information that became an essential part of this document. Thanks also to Kate Harrison for compiling and writing the section on LEED-Home Considerations.

ENDNOTES

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IMAGE CREDIT

All figures are by the author except for those from the following sources:

1. CMHC Website: Figures 7 and 14.
2. Waterloo Biofilter Website: Figure 10.
3. Durisol Website: Figure 18.
4. Professor Terri Meyer Boake of the University of Waterloo: Figures 15, 16, 17, 19, 20 and 23.