WATERLOO GREEN HOME

WATERLOO, ONTARIO

ENERMODAL ENGINEERING
SNIDER REICHARD and MARCH ARCHITECTS

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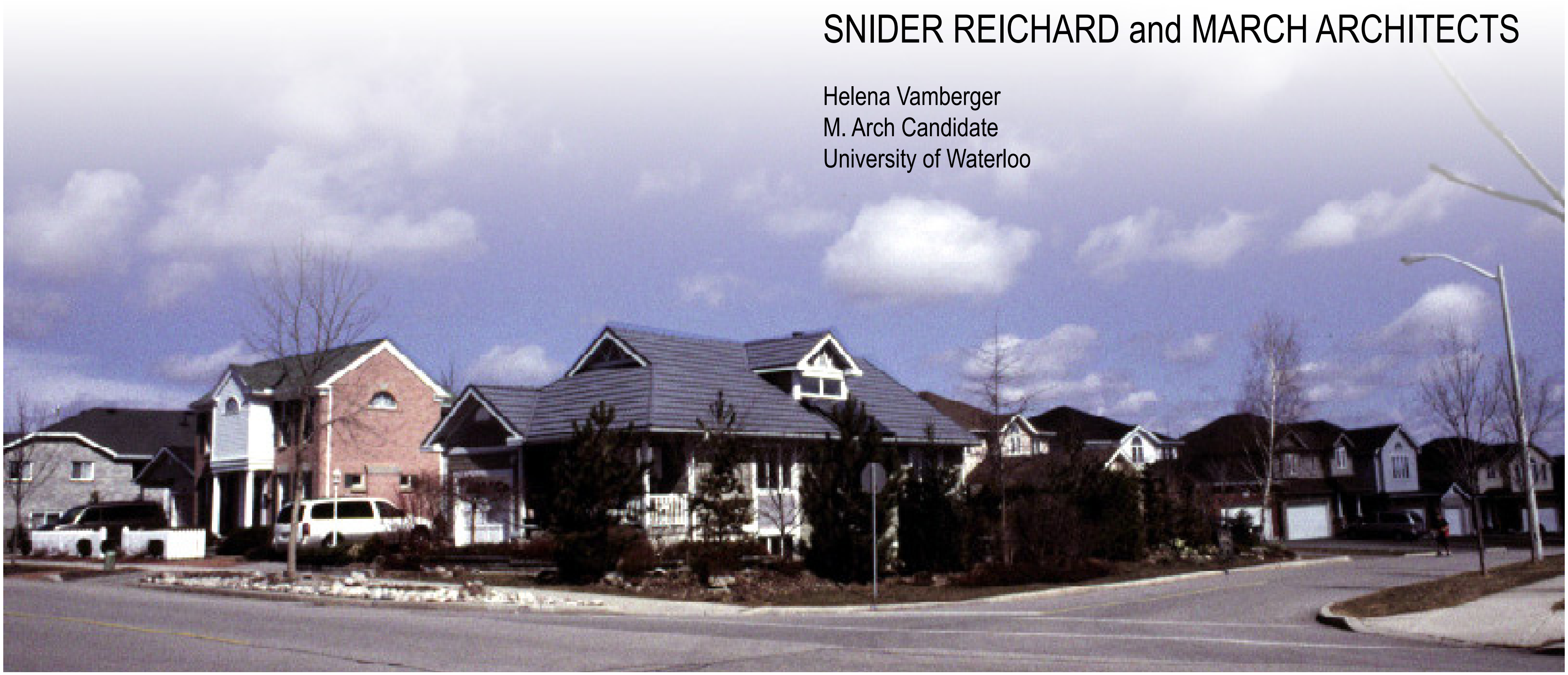

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QUICK FACTS

Building Name	Waterloo Green Home
City	Waterloo, Ontario
Year of Construction	Winter of 1992/1993
Architect	Snider Reichard and March Architects, Waterloo
Program	Detached bungalow, single-family residence
Gross Area	2,500 square feet
Owner/User Group	Thiessen family (five members)
Climate	Cold-temperate

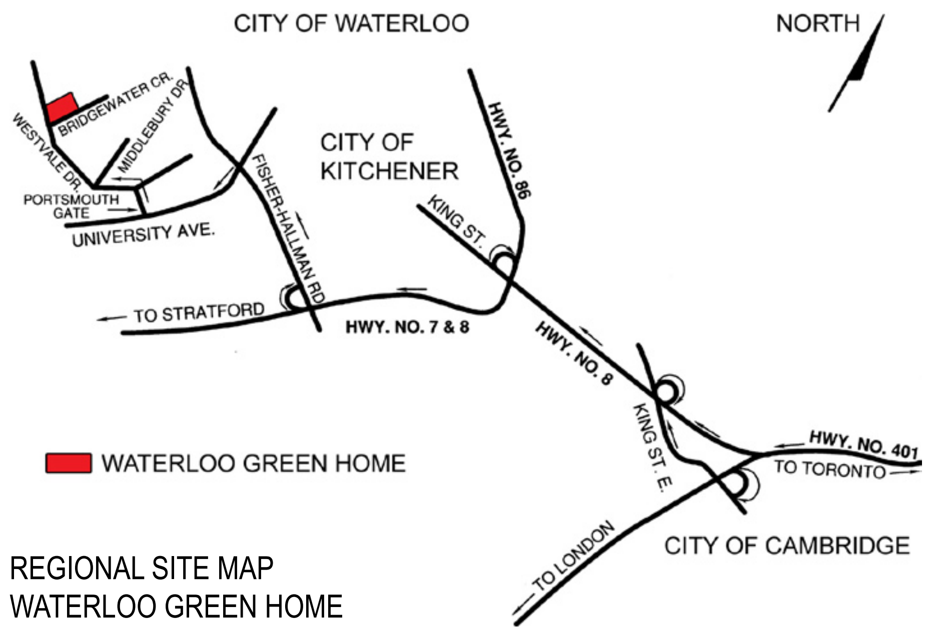
Site Conditions	Corner lot in suburban neighbourhood with south exposure and slight level change
Aesthetic	Designed to blend in with surrounding homes; typical of Canadian suburban bungalows of the early 1990s
Structural system	Wood truss system
Mechanical System	Prototype sealed-combustion gas stove with prototype combination gas furnace and heat recovery ventilator
Special Construction	Pre-cast thin concrete waffle foundation walls
Day lighting	Large, south facing glazing
Shading	West entrance and terrace covered with roof; thermo-active film on clerestory window, trees
Ventilation	Operable windows, and prototype combination gas furnace and heat recovery ventilator
User Controls	"Low tech," and user friendly
Estimated LEED Rating	47 – Gold Status
Budget	N/A
Market Value	Purchased for $196,000 in April 1994[1]
Energy Consumption	Annual energy consumption is 14,026 kWh[2]
Special Circumstances	Designed as a prototype for sustainable suburban homes and demonstration project for prototype technologies employed

INTRODUCTION

The Waterloo Region Green Home was built as a prototype suburban home.[3] The purpose of the project was to demonstrate the application of environmentally sustainable technologies in typical residential buildings, as well as appeal to a wide audience while encouraging the adoption of sustainable construction practices. The project was commissioned under Natural Resources Canada's CANMET Advanced Houses Program in the early 1990s. The Green Home was one of ten houses Canada-wide selected for funding. The project also took part in the International Energy Agency Task 13 Solar Low-Energy Buildings Program. The IEA program promoted the use of passive solar technologies in creating low-energy usage buildings.[4]

The Green Home is located in a typical suburban neighbourhood on the west side of Waterloo, in Southern Ontario. The house was built during the winter of 1992-1993. At the time of construction, the Green Home included the latest technologies and practices in water conservation, energy efficiency, CFC reduction, waste management, and environmentally sustainable materials and finishes. Despite the use of these top-of-the-line, energy-conserving materials and technologies, the Green Home is considered a "low-tech" building.[5] Without computers or other electronic devices to control its interior environment, the building relies on basic passive heating principles in order to function and maintain thermal comfort. Upon the completion of construction in the spring of 1993, the Green Home was opened for public viewing for one year. In April 1994, the house was bought by the Thiessen family, who still live there today.

Although designed by an architectural firm, the project was spear-headed by Enermodal Engineering of Kitchener, Ontario, after winning the CANMET Advanced Houses Program Competition. Throughout the design development



REGIONAL SITE MAP
WATERLOO GREEN HOME

Above Left: Detail view of the entrance vestibule air lock. Below Right: The cathedral ceiling in the great room. Below: The family room in the basement.

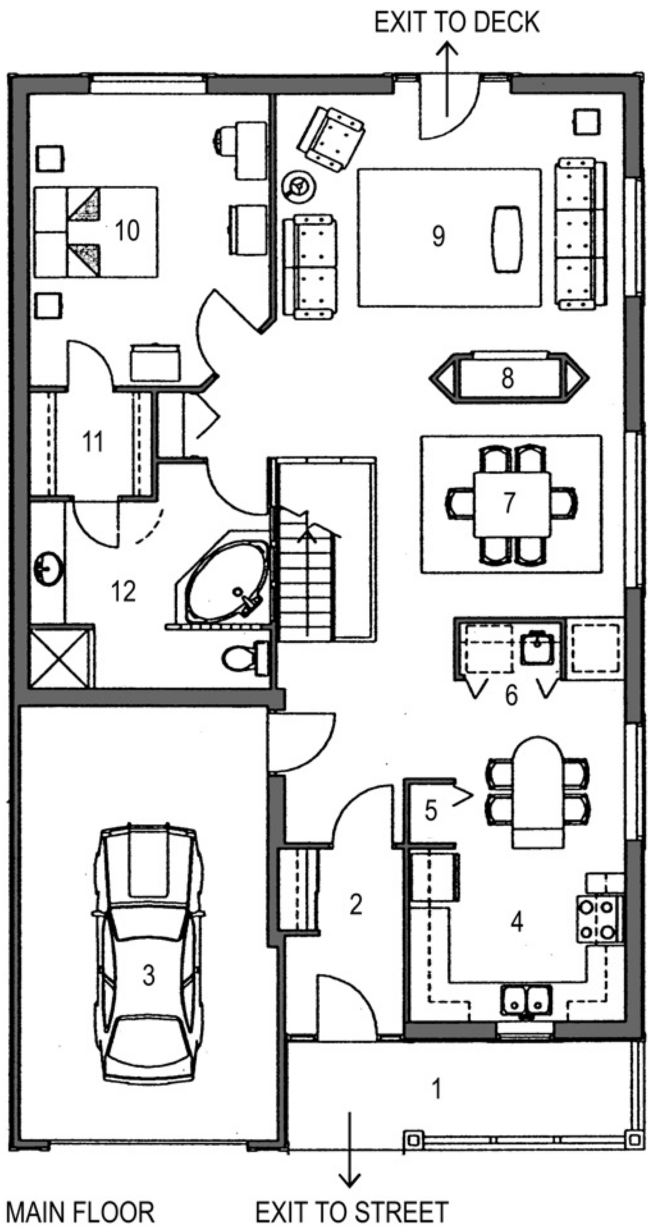
and construction process, Enermodal Engineering acted as principle sponsor, and primary consultant, as well as the overall project and the construction manager. Since the CANMET Competition called for the use of environmentally friendly design, Enermodal decided to use local resources – both material and intellectual – as much as possible. They chose other local companies and businesses to be involved in the design and construction of the project. Ian Cook Construction Limited of Waterloo was hired as the project supervisor while construction was handled by the RTS Homes, also of Waterloo. Architectural services were provided by the Snider Reichard and March Architects of Waterloo. Major project sponsors other than CANMET included the City of Waterloo, the Ontario Ministry of the Environment and Energy, Ontario Hydro, the Ontario Ministry of Housing, the Regional Municipality of Waterloo, and Union Gas Limited. The project was also supported by the City of Kitchener, the Heating, Refrigeration and Air Conditioning Institute, Landscape Ontario Horticultural Trades Association, Waterloo North Hydro, and Kitchener Utilities.[6]

Aesthetically, environmentally sustainable buildings usually express the inherent green strategies employed in the building design in visual terms. In many cases, to the general public these buildings look like high-tech machines rather than comfortable spaces for living. For this proposal, despite its advanced sustainable strategies, the building was designed to blend into the surrounding suburban subdivision. As a result, the Green Home looks like a comfortable and aesthetically pleasing house, both inside and out. Thus, the most significant design strategy employed by the project team was attention to detail. The transition in the neighbourhood from normal suburban home to environmentally sustainable house is seamless, and evident in every detail of the design.[7]

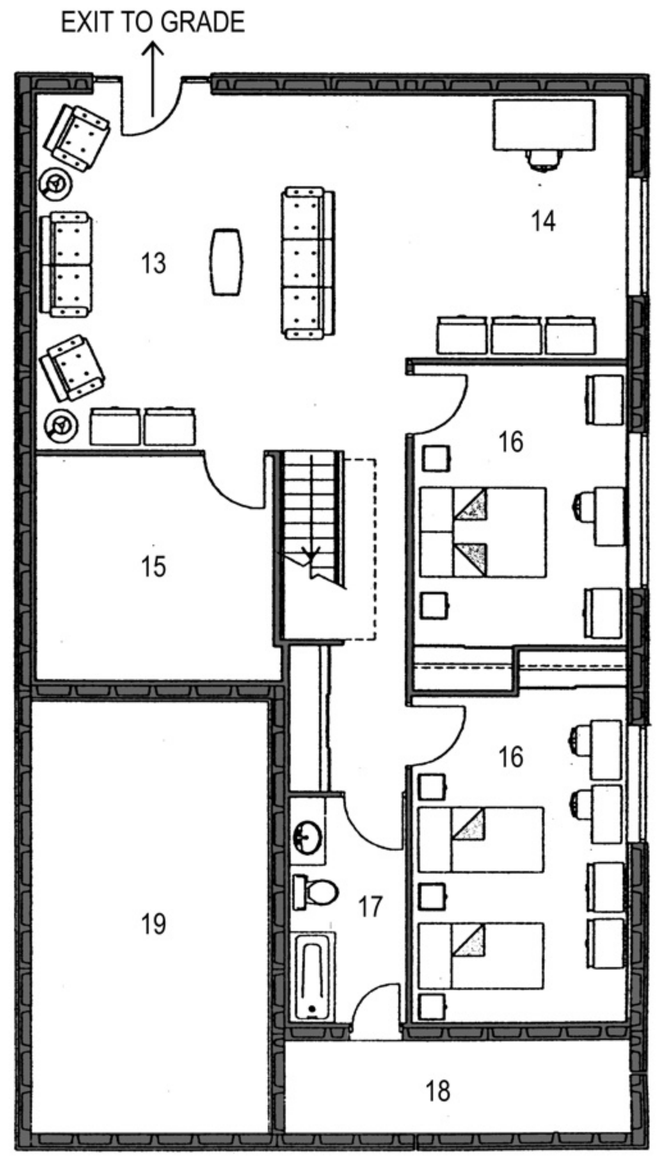
WATERLOO GREEN
HOME FLOOR PLANS

1. ENTRANCE PORCH
2. AIR LOCK/VESTIBULE
3. GARAGE
4. KITCHEN
5. RECYCLING
6. LAUNDRY
7. DINING ROOM
8. GAS FIREPLACE
9. GREAT ROOM
10. MASTER BEDROOM
11. WALK-IN CLOSET
12. FAMILY BATHROOM
13. FAMILY ROOM
14. OFFICE
15. MECH/ELECTRICAL
16. BEDROOM
17. BATHROOM
18. FRUIT CELLAR
19. UNEXCAVATED

NORTH



MAIN FLOOR



BASEMENT

Above: The main floor family bathroom with soaker tub. Below Left: The basement bathroom. Below Right: A planter abuts the fireplace on the main level.

PROGRAMME

The Green House was designed as a single detached bungalow for a family of four with a floor area of twenty-five hundred (2,500) square feet. The main level enters from a small porch or the single car garage into a narrow entrance vestibule and the kitchen, followed by the dining room, the great room, the master bedroom, and the family bathroom. The basement – or ground – floor is connected to the main level by a single-fun open staircase. The lower level contains the family room, two additional bedrooms, the home office, a bathroom, the mechanical room, and a fruit cellar.

Currently the building serves a family of five, although it was designed for a single family composed of parents and two children. Programmatically, the layout of space is organized according to groupings of formal and informal areas, separated by level change. The first floor is for formal – or public – spaces, as designated by the principle entryway, kitchen, dining and great rooms. The informal – or private spaces – such as the family room and the children's bedrooms are located on the lower level with an exit to the backyard. While spaces with greater activity are located within proximity to the building exits to either the front or backyards, the bedrooms are positioned in more recessed corners of the house away from the building exits. The positioning of rooms was also determined by solar orientation; the master bedroom is located on the north-east corner of the house since it is used mainly for rest and sleep, and does not require much natural daylight. The two children's bedrooms on the lower level are located on the south side of the building, indicating their use for study as well as rest.

SITE

The corner lot chosen for the Green Home was selected when the subdivision was still new. The site has a south-west solar orientation, with a grade level change of about one metre. The site was chosen in part due to these features; both the unfettered solar access of the lot and level change were incorporated into the design.

Spatially, the most public rooms with the greatest activity are sited to receive east, west, and south light. There are no windows facing north since the rest of the house's glazing provides sufficient daylight and energy loss from north-facing windows would out-weigh any beneficial views. The lot slopes from south the east, making the basement level partially subterranean: the north wall of the basement is completely buried. The solar orientation in combination with the buried wall helps to reduce the energy needed to heat the building. The interred wall helps moderate the interior temperature because the temperature of the adjacent earth does not fluctuate as much as the ambient air around the rest of the house, and as such, helps reduce interior temperature oscillations.

The careful siting and solar orientation of the building and its spaces could be beneficial in climates other than the cold-temperate one of Southern Ontario. Since the design is intended to maximize solar gain, in hot-arid and hot-humid climates, the building plan would be more successful if it were reverse, placing the public spaces with the most activity on the northern side of the building. The partial interment of the building is a design strategy that can be applied to almost every climate, as the temperature moderating qualities of the surrounding earth work for both hot and cold climates.

Above: The landscape design plan shows mature shade trees on the lot.
Below: The landscaping, pictured in March 2003, still has a lot to grow.

Waterloo Green Home Table 1.1 Energy Rating Comparison[18]		
Building Component	**Typical Home**	**Green Home**
Above Grade Walls	RSI 3.0 (R 17)	RSI 5.9 (R 34)
Below Grade Walls	RSI 1.5 (R8.5)	RSI 4.9 (R 28)
Floor Slab	0	RSI 1.4 (R 8)
Ceiling	RSI 5.6 (R 32)	RSI 10.6 (R 60)
Doors	RSI 0.5 (R 3)	RSI 1.1 (R 6)
Window – Operable	-15	+8
Window – Fixed	-30	+17

Table 1.1 examines the energy rating in RSI and R-values for different building components between a typical suburban home and the Waterloo Green Home. Table 1.2 demonstrates the various U-values for building envelope components.

Waterloo Green Home Table 1.2 U-Values[19]	
Building Component	**U-Value (W/m sq K)**
Roof	0.9
Wall to Ambient	0.15
Wall to Earth	0.15
Wall to Sunspace	0.48
Window	1.10
Sunspace	1.00
Floor/earth	0.63

SUSTAINABLE DESIGN

The primary goal for the design of the Green Home was to construct a dwelling twice as efficient as an R-2000 house (see Table 1.1, Energy Rating Comparison).[8] Consequently, environmentally sustainable strategies were used in every aspect of the building design, from the selection of materials to the arrangement of spaces to the purchase of appliances.

Building materials were selected primarily for their ability to optimize the energy performance of the house, but also for their relative low embodied energy, minimal negative impact on the global environment, and minimal negative impact on the indoor air quality (or IAQ). Subsequently, the design team employed new materials and technologies, always mindful of considerations for locally produced materials, the required code approvals of new technologies, and the adaptability of new products in respect to the building industry.[9]

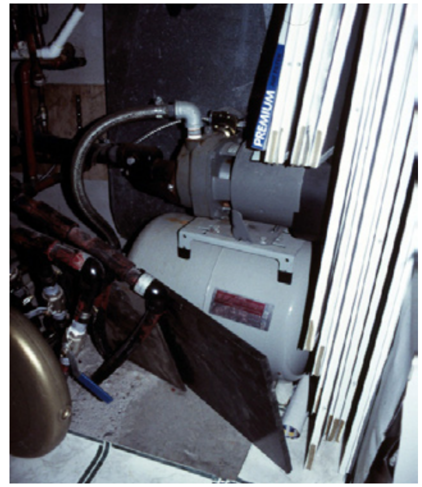
Innovative features and building technologies in the Waterloo Green Home include prefabricated waffle concrete foundation panels, a truss wall system with recycled cellulose insulation, ultra-low-flush toilets, low-E, argon-filled, triple-glazed windows with insulated fibreglass frames, as well as an aggressive construction waste management plan resulting in zero construction waste for landfill.[10] Heating and cooling is provided by a prototype sealed-combustion gas stove and a prototype combination gas furnace and heat recovery ventilator. Hot water is managed by a solar hot water system with a photovoltaic pump that also uses an instantaneous gas water heater for back-up.

The finishes selected for Waterloo Green Home include recycled gypsum board, carpets made from recycled plastic pop bottles, reused wood flooring (originally from a Seagram distillery building located in Waterloo), refurbished bathroom fixtures, and urea-formaldehyde and VOC-free paints and fabrics.[11] The original furniture used for the one-year open house prior to its private sale was selected according to the criteria outlined above as well. However, when the new owners moved in they brought some pieces that were not up to the design standards for the house, causing the IAQ monitoring equipment to be recalibrated. All of the appliances selected for the house were purchased for their minimal energy consumption and low water usage. The energy-efficient appliances included a direct-vent natural gas stove and a non-CFC refrigerator.

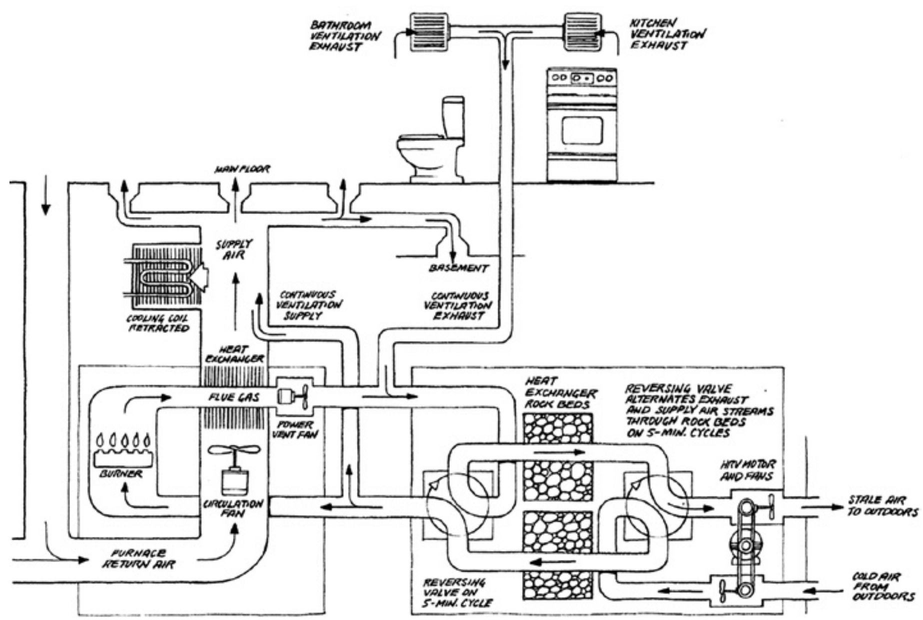
At the time of its design, the impact of the building on its site and surroundings was minimal in comparison to other typical suburban homes of a similar size. The building design respects the solar orientation of the site and the grade level change. Building materials were carefully chosen, allowing the exterior of the building to blend with the surrounding plantings and streetscape. Construction lasted through the winter and spring months so the site vegetation did not suffer, and zero construction waste was sent to landfill.

ENVIRONMENTAL CONTROLS

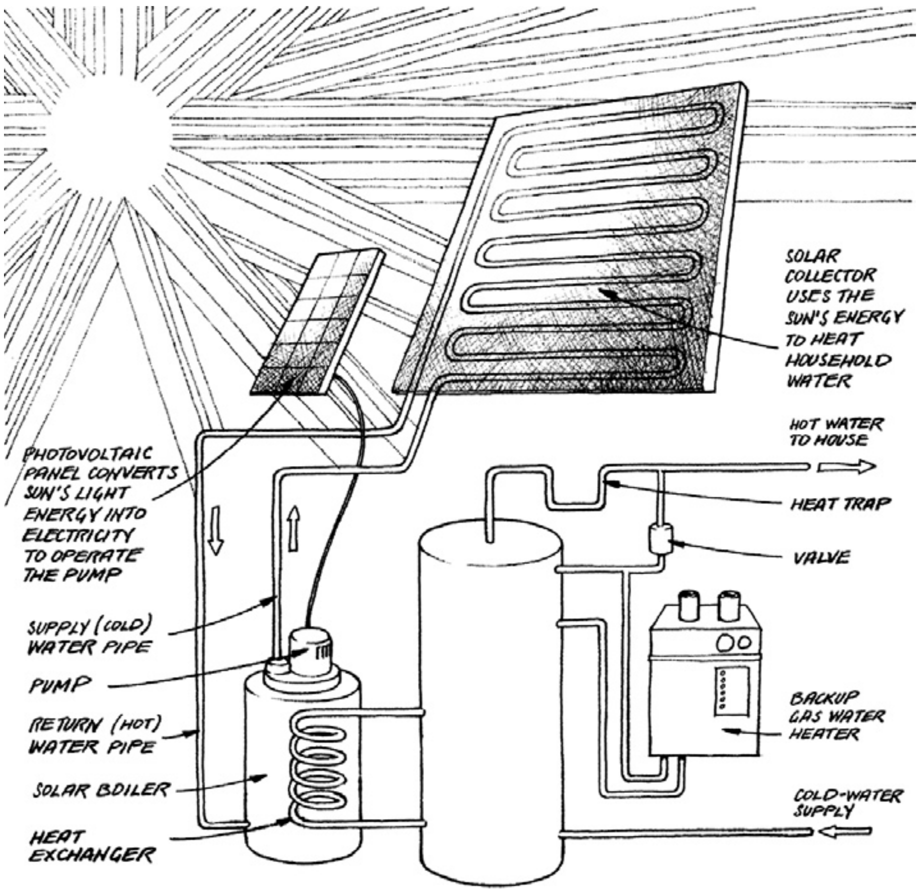
The environmental controls of the Waterloo Green home are user-friendly in comparison to commercial buildings. Passive solar strategies combined with a simple thermostat controlled heating and cooling system, make thermal comfort easily attainable. Solar gain is controlled by roof overhang and thermo-chromatic film on the windows. The ventilation is operated by both passive means – operable windows – and an active heating/cooling system. The landscaping also plays a role in the control of the interior environment by providing shade on the exterior of the building envelope, mitigating unwanted solar gain in the summer months.



Above: Views of the mechanical room equipment. Below: Schematic sketch of the conventional gas furnace combined with rockbed heat-recovery system.



Daylight enters the house from the east, south and west sides. The majority of windows are oriented towards the east and the south. Programmatically, the garage, entrance vestibule, and the kitchen are positioned on the west side of the house. The front terrace, integrated with the roof overhang, shields the entrance and the kitchen window from much of the harsh afternoon light.



Schematic of the photovoltaic hot water heater located on the south facade.

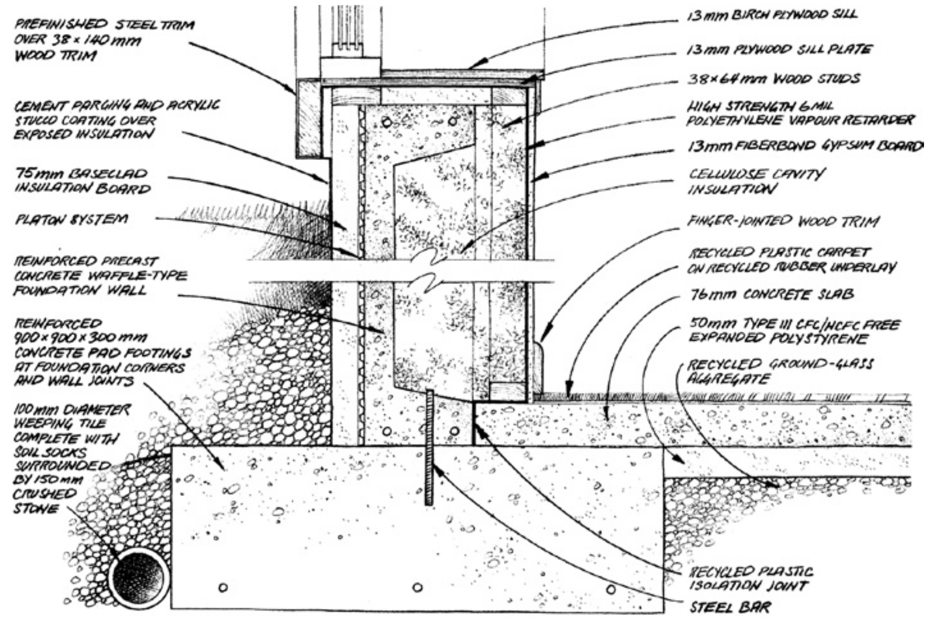
The south and east façades do not have large overhangs, since the window openings are sized to allow for solar gain as part of the overall heating strategy for the building. Aside from a large window, the south façade also includes a clerestory window positioned above the dining room area. The clerestory window is operable and is covered by a thermo-chromatic film. When the temperature at the clerestory window rises above 26°C the film becomes white and opaque. In doing so, the sun can no longer penetrate the interior space with the same intensity, thereby controlling the thermal temperature of the main floor space. The basement level receives only east and south light; the north and west façades are buried beneath the grade level change. Consequently, areas that are not regularly occupied are placed on the north and west sides of the basement level. On the west is a fruit cellar, and the mechanical room is located in the north-west corner. Because of the spatial planning of the ground level designating spaces of low-occupancy adjacent to windowless walls, the openings on the east and south sides are large enough to provide sufficient light for the entire basement.

Ventilation is managed by a continuous mechanical ventilation system and operable windows. All windows on both levels are operable and positioned to encourage the natural venting of spaces. The Green Home is designed with both passive and active strategies for heating and cooling. The Theissen Family – the current occupants – admits to the use of active strategies for heating during the harshest winter months. Whereas, at other times of the year passive heating strategies are sufficient.

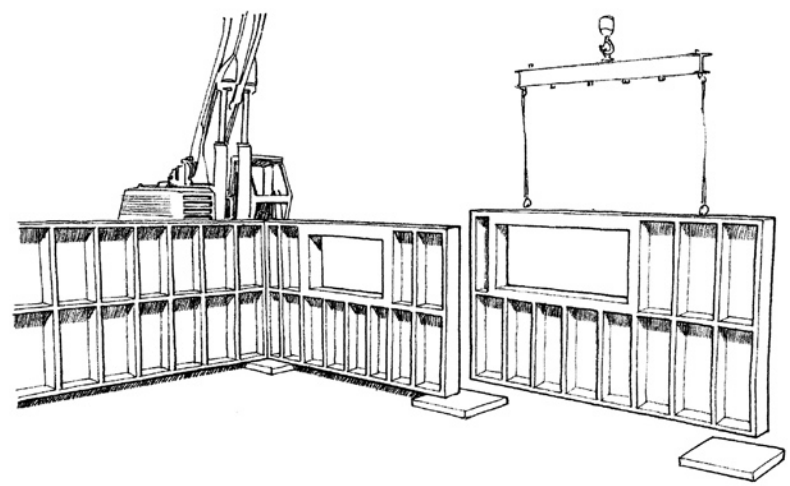
The landscaping of the Waterloo Green Home is another aspect of environmental control for the house; it helps mitigate solar gain on the south and east elevations. The treatment of the exterior landscape focused on two principle goals: 1) the use of native plant species to ensure heartiness, use less water for irrigation, and minimize up-keep, and 2) make the landscape enjoyable for people as well as local suburban wildlife, such as migratory birds. Because of the gradual slope from the front to the back of the year, stormwater that is not absorbed by the pervious soft landscaping drains away from the house.[12] The overall landscaping was not complete at the time of sale of the house in April 1994; however the new owners continue to maintain the original landscape design.

To create a successful landscape, the original heavy clay subsoil was mixed with gypsum chips made from recycled drywall, whereas the topsoil was treated with organic compost from a nearby mushroom farm. The plants selected were native to Ontario, including many evergreens, but no annuals, since plants needing to be replaced each year was considered to be too energy consuming. The landscaping requires little keep-up and next to no watering. In contrast to the other surrounding suburban homes, the lawn of the Green Home is created from buffalo grass and white clover which require no watering or mowing, and is contained in relatively small areas in the front, side and backyard. The rest of the site is covered with native trees and shrubbery planted to shield the Home's windows from the sun during the summer months.[13]

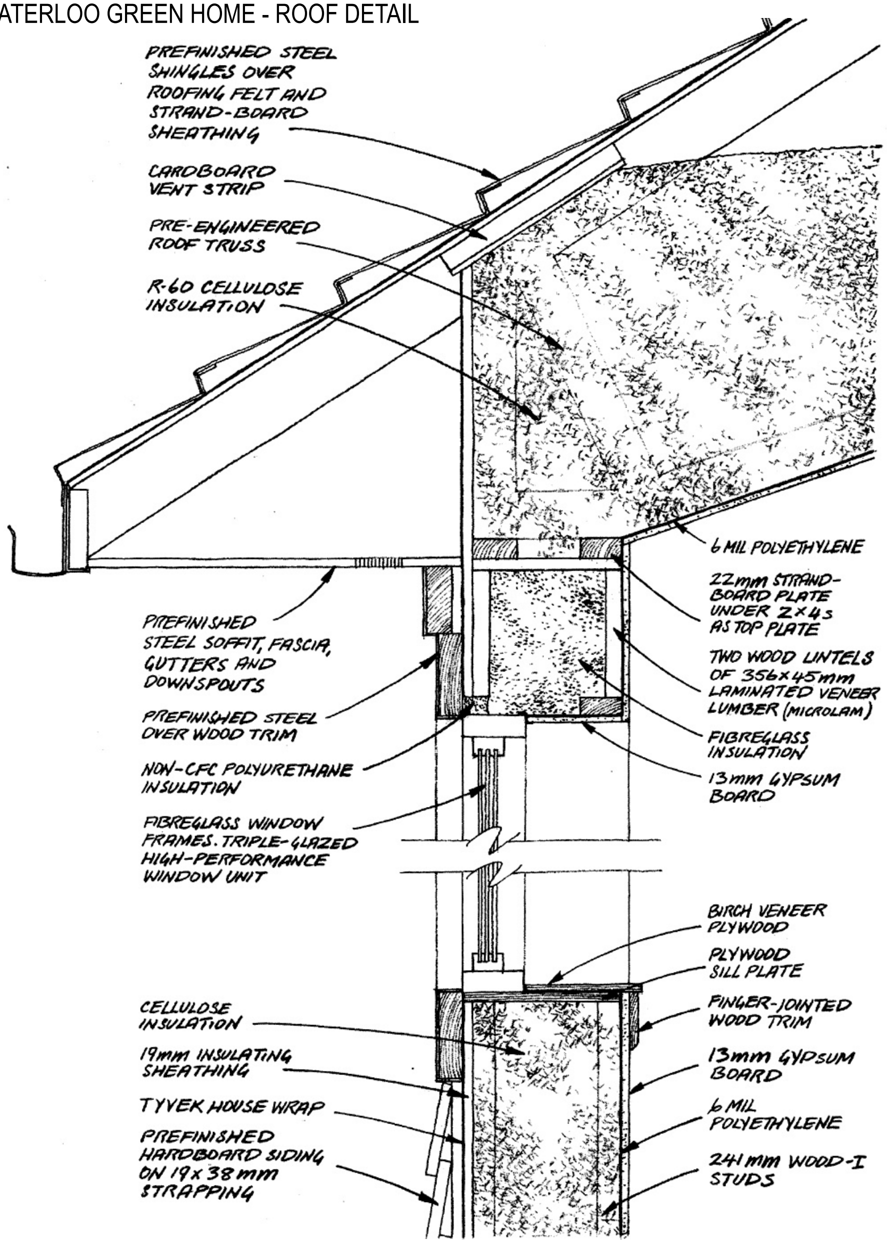
The Waterloo Region Green Home demonstrates the feasibility of both passive and active heating and cooling strategies that work in the Southern Ontario climate. These strategies need to be tailored for other sites according to the amount of sun, solar orientation, and snow that area receives. However, in general, most places in the world with similar climatic conditions could benefit from incorporating many of the passive and active strategies explored in the Green Home into their building designs.



Above: Detail of the foundation wall with the connection of the pre-cast concrete panels. Below: A sketch of the waffle concrete panels lifted in place.



WATERLOO GREEN HOME - ROOF DETAIL



CONSTRUCTION

The Waterloo Green Home was constructed during the winter between 1992 and 1993. The building was designed to be well-insulated and to have an air-tight shell. The below grade walls of the basement level are made from pre-cast, thin concrete panels resembling a large waffle on the inside with the smooth surface on the exterior. The fabrication of the waffle foundation wall required approximately 50% less concrete that a generic foundation wall for the same size of bungalow. The concrete mixture used for the waffle-panel walls was high-density and high-strength at 35 MPa (7000 psi). The mix was made with the use of a chemical super-plasticizer, a higher cement-to-aggregate ratio, and a low water ratio.[14]

The concrete waffle foundation walls made of large and small panels are bolted onto cast-in-place foundation footing pads. The large panels measure eight (8) feet in height, sixteen (16) feet in length, and weigh 6400 pounds each. The smaller panels are half the size. The seams where the foundation wall panels meet each other and the footings are sealed with strips of Waterstop, overlapping an inch to either side. Platon, a black, 24-millimetre thick, high-density polyethelyne damp-proofing membrane with dimples on the interior side and a smooth surface on the outside, was used to waterproof the foundation walls on the exterior.[15]

The foundation wall is filled with recycled cellulose insulation, with the exception of the fruit cellar that was designed without insulation to keep a constant cool temperature. The fruit cellar temperature does not fluctuate much since it is buried underneath the entrance porch and receives no sun exposure.

The basement floor rests on a bed of recycled crushed coloured glass. The first floor is made from a system of prefabricated wooden I-beams called The Truss Joist Silent Floor System. The I-beams are made from two by four inch wood beams joined with a strip of plywood. The joists are spaced at twenty four inches increments. The roof uses prefabricated trusses made from dimension lumber no larger than a typical two-by-four board. All the wood used for the structure of the house is from rapidly renewable forests, and most of the sheathing is made out of the aspen wood chips.[16]

The above grade walls are constructed from a wood truss system using rapidly renewable resources, and measure three hundred (300) millimetres in thickness. They are also filled with the recycled cellulose insulation. The exterior finish of the house is comprised of four by eight (4 x 8) foot Excel Board sheathing panels that are made from a blend of polyisocyanurate foam and aspen fibres. All the openings in the walls for doors, windows and vents, have a twenty-four (24) inch strip of six mil poly wrapped around the inside edge and caulked to the vapour barrier to prevent air leakage.[17] The rest of the shell construction is the same as any other typical suburban home.

INTEGRATION OF SYSTEMS

The design for the Waterloo Green Home is based on a “low-tech” concept so that the active mechanical system – although very important in a Canadian climate – becomes secondary to passive means. The active mechanical system acts as support for the passive heating, cooling, and ventilation of the house received from the sun, the earth and the wind. In a typical suburban house, the active mechanical system is the primary means of keeping the building liveable. Consequently, its structure is designed to allow for ducting and other equipment to run as efficiently and effectively as possible. In the case of the Waterloo Green Home, the structure allows for the active mechanical system; however it

WATERLOO GREEN HOME - UPPER FLOOR WALL DETAIL

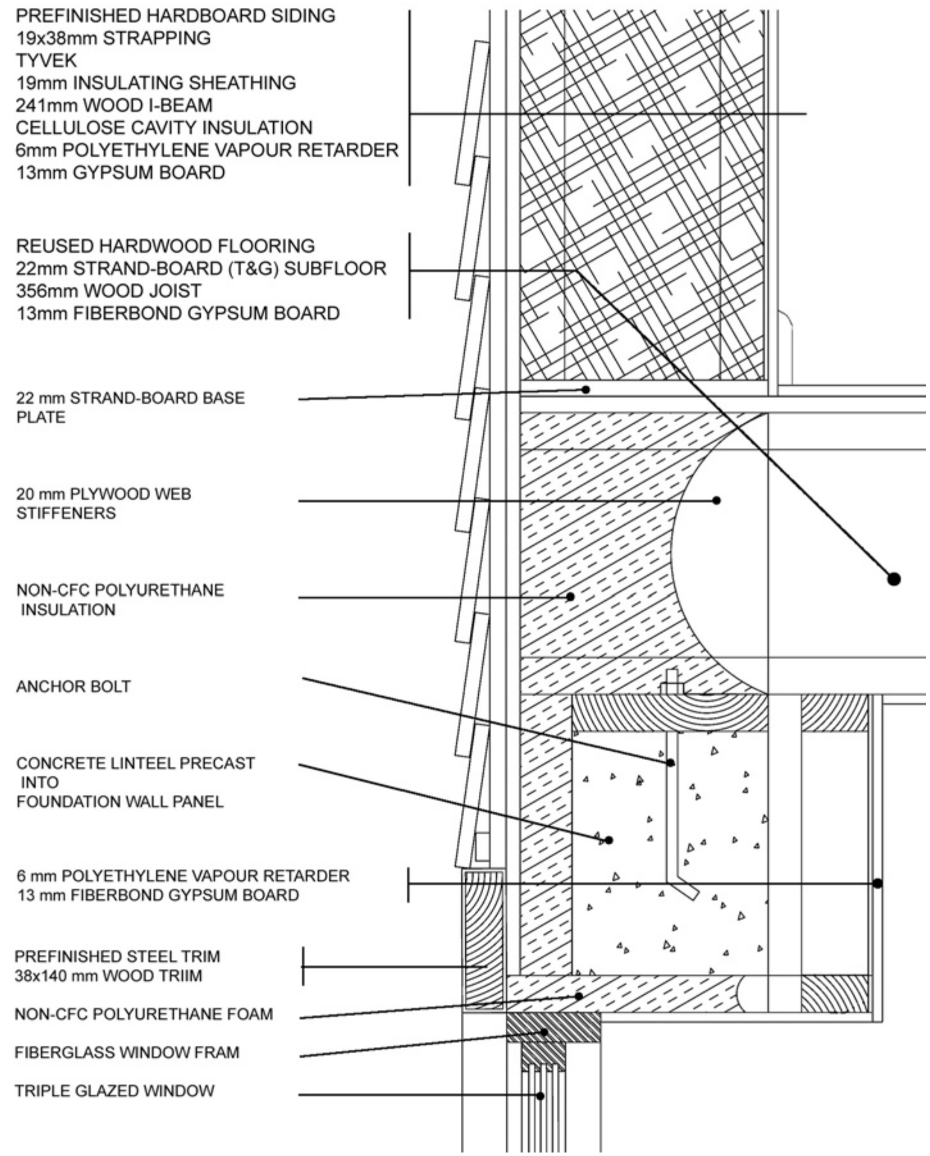


Table 1.3 Predicted Energy Demand[20]	
Building Component	**Energy Demand (kWh/m² a)**
Space Heating	25
Space Cooling	1
Water Heating	5
Lights & Appliances	17
Fans & Pumps	8
Total:	**56**
Total Heated Floor Area:	208 m²
Energy Demanded per m²	0.27 kWh

Tables 1.3 and 1.4 compare energy consumption with energy costs (1993 $).

Table 1.4 Energy Costs Per Year ($) [21]			
Building Component	**Typical (Electric)**	**Typical (Gas)**	**Green Home**
Space heating	935	343	97
Water heating	447	230	97
Cooling	157	157	21
Natural gas appliances	0	0	29
Electric appliances	519	519	160
Lighting	118	118	54
Fans	175	175	173
Gas fixed charge	0	90	90
Water and sewage	345	345	106
TOTAL Cost	**$2696**	**$1977**	**$748**

is designed primarily to support the passive heating and cooling strategies. In comparison to a rudimentary suburban home, the mechanical and the structural system of the Green Home exist interactively, since the structure was designed to support both active and passive systems. While the physical structure of the building carries the water- and air-tight envelope, the mechanical system uses rocks to cool and filter the indoor air. It also makes use of cistern water that is circulated through a coil in the air handling system to provide for summer cooling.

COSTING

The Waterloo Green Home was sponsored by a variety of people and organizations interested in supporting innovative environmental design. Despite the many grants and additional funding, the bulk of costs were from the innovative design process itself, coordinated by Enermodal Engineering. The greater part of additional design hours went into researching appropriate materials, equipment, and the craftsman capable of handling the requested environmental design.[22] According to Enermodal, the total cost of the project exceeded the average suburban home of the same size in the same area by 15 to 20%. It was sold for $196,000.00 in 1994 – a 15-20% increase above the cost of other bungalows in the Waterloo area. Other cost over-runs also came from the use of several prototype technologies and measures to control the quality of the indoor air such as sealing the kitchen cabinets to prevent the release of urea-formaldehyde.

Conversely, the annual energy cost of the home is 72% lower compared to other suburban houses – calculated with 1992-1993 figures for electrical heating, when energy costs where still relatively low (Table 1.4). Monitored between 1993 and 1994 by Enermodal Engineering, the house demonstrated a peak heating requirement of 4 kW, and its annual energy consumption is below 4000 kWh.[23] The cost of landscape maintenance is nominal and the owners hardly use any commercial fertilizers. The up-keep of the house is also kept to a minimum, since it is still very new. Up until now the structure or envelope of the house has required no repair.[24]

The owners have experienced problems with the active mechanical system, since the solar hot water system breaks down every so often. The problem is due to the lack of continuous high volume use of hot water. If hot water use is suspended for any reason, such as holidays or travel, the hot water stays in the tubes. The stagnant hot water combined with the scorching sun overheats the glycol in the panels. When the glycol becomes overheated it becomes viscous and it needs replacing in order for the system to function properly again. A second minor problem was the three-litre low flush toilet. Its motor was too loud, causing the Thiessen family to quickly replaced it with a quieter five-litre low-flush tank.[25]

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

The estimated LEED rating for the Green Home is based on the current LEED Version 2.1 document. Although the focus of the rating system is all buildings except low rise residential, the system gives a good overall indication of the sustainability of the Green Home project. The assessment of the Green Home precedes the implementation of the LEED Home rating system, offered as of September 2004. For this reason, the Green Home lost points in categories aimed directly at larger, commercial type developments. Despite this, the Green Home scored well in all six categories of the rating system except for Innovation and Design. According to LEED criteria, the Green Home did not display any exceptional innovation above and beyond the scope of the rating system.

LEED GREEN BUILDING RATING SYSTEM 2.1

Project Checklist	
Sustainable Sites	**9**/14 Possible Points
Water Efficiency	**4**/5 Possible Points
Energy & Atmosphere	**15**/17 Possible Points
Materials & Resources	**7**/13 Possible Points
Indoor Environment Quality	**12**/15 Possible Points
Innovation & Design Process	**0**/5 Possible Points
Project Totals	**47**/69 Possible Points
Waterloo Green Home Result	**Gold Status**

In terms of the Sustainable Sites category, the Green Home scored well for Alternative Transportation measures by being close to two Grand River Transit bus stops and having an alternative refuelling station in the garage. Stormwater management is well handled by the landscaping, and shade trees provide protection from the sun. In terms of Water Efficiency, the lack of a permanent irrigation system and planting of native species in yard help reduce the use of potable water for landscape irrigation to zero. With the help of low-flush toilets and aerator faucets, the Green Home was also able to reduce its water consumption by 60% over conventional homes of the same size. In terms of energy performance, the Green Home by far surpasses the optimal energy performance by offering 72% savings over conventional electrically heated homes. This was achieved in part by an extensive commissioning plan and the continuous measurement and verification of the systems over the first year following its completion. In terms of Materials and Resources, the design team took extra care to specify materials that were salvaged, locally manufactured and harvested, as well as those with a high recycled content. The indoor environment quality of the Green Home also scores well in the LEED rating system for the attention paid to low-VOC adhesives, paints, carpets, furniture, and wood products. Thermal comfort is maintained through a combination of passive and active systems, and daylighting and views are available to all regularly occupied rooms. In total, the building's estimated LEED rating is 47 out of 69 possible points, achieving the Green Home LEED Gold status.

CONCLUSION

Built as a prototype project, the Waterloo Green Home demonstrates the highest standard of environmentally sustainable design available at the time of its construction. Its environmental sensitivity is shown in all aspects of the project; from the selection of the lot, to the programming of the floor plans, its construction, structure, mechanical systems, materials, finishes, appliances, and the design of its landscape. In short, the project is a well-integrated sustainable building.

Although newer and more efficient technologies exist today, at the time the Green Home used top quality products that adhered to the strict environmental criteria established by the design team. The performance of the Waterloo Green Home in terms of the use of water and energy attests the quality of research and design that went into the project. In addition, the current residents also prove the liveability and performance of the demonstration project as a successful home. As a result the Thiessen Family is not thinking of selling the Waterloo Green Home any time soon – if ever.

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