The Archetype Sustainable Houses: Overview of Design and Monitoring Systems

Living City Campus at Kortright, Vaughan

Toronto and Region Conservation
Ryerson University

Final Report 2011

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Final Report

Prepared by:

Toronto and Region Conservation's Sustainable Technologies Evaluation Program

based on research reports and papers prepared by faculty and graduate students from Ryerson University's Department of Mechanical and Industrial Engineering, and Department of Architectural Science

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- assess barriers and opportunities for implementing technologies;
- develop supporting tools, guidelines and policies; and
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical structures; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and liveable communities.

ACKNOWLEDGEMENTS

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Region of Peel
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The construction of the Archetype Sustainable Houses was made possible through a partnership between the Toronto and Region Conservation Authority and the Building Industry and Land Development Association (BILD), many members of which contributed labour and materials to the project.

A comprehensive list of the many generous sponsors who contributed to construction of the houses is available at www.sustainablehouse.ca.

EXECUTIVE SUMMARY

The Archetype Sustainable House is a semi-detached twin house designed to serve as a model or prototype for the next generation of "green" production homes. The two houses differ in that House A is intended to demonstrate technologies that are practical today while House B showcases those of the near future (Fig. 1). The goal of the project is to demonstrate and evaluate sustainable housing technologies, materials and practices as a means of influencing how production homes are designed, built and lived so that ecological footprints are minimized and quality of life is improved. This first report provides a summary of the green features and innovative technologies installed in the houses, and details the process of developing and installing a system of sensors and data acquisition hardware and software for monitoring of energy performance.

Figure 1: Archetype semi-detached twin Houses A (right) and B (left)

The project was initiated with a national competition conducted in partnership with the Design Exchange. The intent was to engage architects, engineers and graduate students from across Canada to design a mass production green home for new community development. Of 17 entries, the design submitted by the Building Blocks Partnership was selected as the winner by a blue ribbon panel of judges. The houses were constructed in the summer of 2008 at the Living City Campus at Kortright in Vaughan, roughly 15 km north of Toronto.

Unlike other sustainable house demonstration projects, the Archetype Sustainable House will remain open to the public indefinitely, serving as an ongoing education and training centre for builders, colleges, universities, and the public. Energy efficient features and equipment have been installed in a manner that facilitates removal and replacement to allow testing and evaluation of newer technologies and approaches as they become available. Monitoring of the various innovative technology component systems in the houses will provide valuable insight into their effectiveness in the local climate and serve as a basis for improving on technology designs where needed.

House Design

Architecture

The Building Blocks design of the twin houses allows stacks of blocks to be combined in pairs (semi-detached houses), rows (row houses or stacked townhouses) or slotted in between existing buildings (urban infill) to create diverse and interesting communities. The following are some of the most important features of this unique design concept.

- **Modularity**. Modular building blocks offer a range of design options without the high cost of customization. There are four different housing types to suit different lifestyles: detached, semi, row and townhouses from 2-7 bedrooms.
- **Adaptability/Affordability**. An attached garage and fully finished attic offers adaptable use with potential for rental income.
- **LEED and Energy Star Certified**. Third party environmental certification verifies best building practices. The house has been third party certified as a LEED-platinum building – the highest rating possible in the LEED green building rating system.
- **Superior Insulation and Air-Tightness**. The Sustainable Archetype House offers year-round comfort and low utility bills by means of high-grade insulation and a secure building envelope.
- **Interior Design**. The open concept design makes the most of natural light and air flow. A recycled wood staircase lets in daylight and creates natural stack effect ventilation. The kitchen features recycled material counters, energy-efficient appliances and low flow fixtures.

Heating, ventilation and air conditioning

Each of the two houses has their own HVAC and water systems. A central design feature of the twin houses is integration between its components. For example, House B uses a geothermal ground loop as both a heat source and sink. By integrating this system with the radiant floors and ventilation system, House B regulates its temperature efficiently without burning gas.

There are two major components of the ventilation system: (i) the Enthalpy Recovery Ventilator (or Heat Recovery Ventilator in House A) and (ii) the Air Handling Unit. The ERV captures heat from the exhaust air to pre-heat incoming fresh air, thereby reducing the energy consumption of the AHU. The ERV in House B differs from the HRV in House A in that it can transfer a certain amount of water vapour along with heat energy while the HRV only transfers heat. The AHU, which is integrated with an air-to-air heat pump, has a variable speed fan and supplies forced hot air to the zones above the basement for space heating.

Insulation features include super-insulated walls, floors and roof, super-efficient windows and doors, and passive solar features such as deciduous trees and an ivy trellis that shade the house during summer months but lose their leaves in the winter to let light through.

Water heating

Integrated space-water heating systems in each of the houses combine the functions of space and water heating to reduce the capital cost of equipment and increase operating efficiency.
In House A, a solar combi-system[1] with an active flat plate solar collector is used for domestic hot water heating, along with auxiliary gas heating. A wall-mounted mini boiler is used for auxiliary heating when the solar collector alone is not sufficient. The mini boiler also aids in space heating by supplying water for the radiant heating system in the basement. The hot water system of House A is a one-tank system, which serves as both a solar hot water and time-of-use tank.

Like House A, House B has a solar combi-system with an auxiliary heat source, which in this case is electricity rather than gas. The solar combi-system uses an evacuated tube for space and water heating. The house uses a two-tank rather than one-tank system; one tank is the solar hot water preheat tank and the other is the time-of-use based electric hot water tank which receives additional heat from a ground source heat pump.

A micro cogeneration system has also been installed in House B and can simultaneously produce electricity and heat water for household use or space heating. Hot water used in the radiant heating system of House B is stored in a buffer tank. During the summer, the buffer tank also supplies cold water to the AHU to cool down the incoming fresh air in the ventilation system.

An important system installed in both houses is the drain water heat recovery system, in which a power pipe coils around the main drain pipe to recover drain water heat (e.g. shower, laundry).

Electricity generation and conservation

Both Houses have various measures installed for conserving electricity, including Energy Star® appliances which consume 15 to 50% less energy and water than standard models (NRCan, 2009c) and compact florescent bulbs, which consume less power and have a longer rated life. Of the two houses, only House B has systems for generating electricity. There are three electricity generating systems connected to House B:

Solar photovoltaic array. The PV system on House B has a total of 48 modules, each with an 85 watt capacity. The total array area is 31 m^2 and the generation capacity is 4.08 kWp.

Household-sized wind turbine. Connected to the main electrical panel in House B is a 1.8 kW grid-tied wind turbine. The horizontal axis turbine has non-furling blades and is mounted on a 50 ft tilting monopole. It is net-metered, offsetting House B's electrical bill by slowing down the electrical meter, and even turning the meter backwards during periods of low electricity demand.

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[1] A solar combi-system is a solar heating system that provides space heating and cooling, and hot water. It is often linked to an auxiliary heat source, such as gas or geothermal.

Micro cogenerator. Installed in the basement of House B, the system uses a Whispergen Stirling engine powered by natural gas to generate electricity, while capturing waste heat from the generator for water heating.

Stormwater management and water conservation

The Archetype Sustainable House contains several technologies to maximize efficient use of water, and minimize both stormwater runoff and the demand for municipal water supply. While the houses have different technologies installed, some systems are connected so that excess water supply in one house supplements the supply in the other.

A green roof installed above the garage in House A provides an opportunity for significant retention of rainfall incident upon the roof. Downspouts draining water from the roof of House A are extended out to the garden away from the foundation, to demonstrate the proper method for disconnecting a downspout from the storm sewer system. A Brac™ system installed in House A is an important water conservation measure. It allows for the collection of grey water from the showers in House A. The water is collected in a 150 litre barrel, filtered, chlorinated and pumped out to supply water for toilet flushing.

In House B, rainwater is collected for re-use in two ways: a rainwater harvesting cistern and a simple rain barrel. All stormwater draining from the south side of the roof of House B and the roof of the in-law suite is conveyed to a 10,000 litre underground concrete cistern. Water collected is filtered and pumped into House B for use in toilets, and to the hose bibs of both houses. It also serves as a back-up supply of water for the grey water system in House A. House B’s 170 litre rain barrel collects all runoff from north side of the roof and overflows to the garden when full.

Systems common to both houses are the permeable pavement driveways, wetland wastewater treatment system, xeriscaping and water efficient appliances and fixtures. Both houses have individual permeable pavement driveways, which allow for full infiltration of rainfall through the pavement and base course and into the native soil. The wetland wastewater treatment system is a single system that treats wastewater from all sinks and toilets in both houses. It consists of a septic tank, two wetlands, and tile bed in which the treated effluent is infiltrated into the ground.

Monitoring Program

Monitoring of the technologies at the Archetype Sustainable House was initiated in 2008 and is being carried out to track and evaluate the performance of the energy, water, and ventilation systems of the twin houses. To date, the houses have been instrumented with over 300 sensors and a state-of-the-art National Instruments data acquisition system to allow the buildings and their component systems to be monitored continuously for research and educational purposes.

As part of the energy monitoring program sensors have been installed throughout the houses to measure and record: (i) thermal energy flow, (ii) air flow and humidity, (iii) water flow, and (iv) electricity. Outdoor meteorological conditions are measured simultaneously at a nearby meteorological station. All sensor data collected are logged and analyzed by the data acquisition system, which collects raw data from all sensors, and uses a software platform called LabVIEW to convert sensor output signals into the corresponding units and carry out other data analyses and calculations. All data are stored directly in a local SQL server database.

Energy Audit

An energy audit was conducted on the twin houses on December 16, 2009. The audit involved a depressurization test, a building energy simulation, and thermal images taken to identify potential locations of infiltrations, leakages, and thermal anomalies within the building envelope.

The depressurization test results (Table 1) showed that air changes per hour (a measure of air tightness, with a lower value indicating a more airtight building) were under 1.5 for both houses, which is considered very airtight, making the houses eligible for R-2000[2] certification. As a comparison, and Energy Star home can have an air tightness value as high as 2.5 ACH@50pa, and the 2012 Ontario Building Code standard is 3.1 ACH@50pa.

Table 1: Air Tightness results for individual testing of Houses A and B

Parameter	House A	House B
Net floor area (m^2)	345	350
Internal volume (m^3)	986	1036
Volumetric Flow rate (CFM)	698.5	665.0
Air changes/hour @50 Pa (ACH)	1.204	1.091

In the building energy simulation, Natural Resources Canada's HOT2000 version 10.50 software was used to evaluate the energy performance of the twin houses. The simulation revealed that House B performed better than House A, which is largely a result of more efficient mechanical equipment and a better insulated building envelope in House B. It was also determined that both houses were more energy efficient than the R-2000 building standard, which has significantly higher efficiency requirements than the current Ontario Building Code.

Next steps

The Archetype Sustainable Houses have been designed as a living laboratory for green building technologies. As evaluations of the systems originally installed in the houses are completed, the information obtained and lessons learned will provide valuable information on the effectiveness of the existing technologies, and potential areas of improvement. The following options are currently being considered for evaluation in the twin houses:

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[2] The R-2000 Standard – administered by Natural Resources Canada – is an industry-endorsed technical performance standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction.

- Addition of ClimateWell® thermal cooling to the cogeneration system in House B, making it a trigeneration system, which is capable of harnessing the waste heat to simultaneously generate electricity, heat and cooling.
- Installation of a Heart™ Transverter, an electrical power conversion device capable of combining electrical power from various sources and converting power between different voltages and AC or DC. The transverter would allow the house to go temporarily off-grid in the event of a power outage and also help to improve power factor[3] on site so that electrical power is being used more effectively and transmission losses to the grid are reduced.
- Installation of a Building Integrated Photovoltaic/Thermal (BIPV/T) collector to be coupled with a two-stage variable capacity air source heat pump (ASHP). Heat energy taken from the back of the BIPV/T collector will be used to pre-heat air and thereby improve the efficiency of the ASHP while keeping the PV cool so that it operates more efficiently.
- Improving landscape-based stormwater management by adding measures to optimize absorbency and minimize stormwater runoff from the site, including a rock garden, rain gardens, and herb and vegetable gardens. Recommendations will be developed based upon monitoring data collected from this site and others, as well as community scale implementation and demonstration projects in Brampton, Richmond Hill and Toronto through TRCA's Sustainable Neighbourhood Retrofit Action Plan.

Monitoring of the houses and the individual systems within them will continue with an emphasis on generating realistic energy and water consumption patterns. This will be achieved in two ways: (i) develop and apply established load profiles with automated switch features to simulate a family's energy and water consumption, and (ii) allow the twin houses to be occupied by residents for a fixed period of time. Data collected during occupancy, or when load profiles are applied, will provide insight into how well the systems perform when subject to real life consumption patterns and also form a basis for comparison to other conventional or energy efficient homes.

Also planned in the near future is the posting of monitoring data (from the data acquisition system's LabVIEW software) on the web. The display data will be near real-time and available for viewing on in-house televisions by touring visitors as well as on existing websites affiliated with the Archetype Houses.

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[3] The ratio of actual power being used in a circuit (in units of watts or kilowatts) to that of the power being drawn from the power source, usually the power grid (in volt-amperes or kilovolt-amperes). The difference between the actual power being used and the power drawn from the source represents the amount of power that is lost and does no useful work. Power factor is typically expressed as a ratio between 0 and 1.

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1.0 INTRODUCTION

1.1 Context

Mitigating global climate change requires all countries, sectors and individuals to make unprecedented efforts to reduce greenhouse gas emissions and shift to more sustainable technologies, practices and lifestyles. Improving the efficiency and performance of housing with respect to energy, water and material use are ways that everyone can contribute to reducing greenhouse gas emissions.

Residential energy use, or the energy consumed through construction, maintenance and operation of homes represents a significant portion of overall energy use and greenhouse gas emissions. Between 1998 and 2004, the housing sector accounted for 17% of secondary energy use[4] in Canada and 16% of the country's greenhouse gas emissions (Natural Resources Canada, 2006). Space and water heating are the dominant residential end uses of energy, typically representing 58% and 22% of total household consumption, respectively (Cuddihy et al., 2005). The residential sector accounts for 56% of all municipal water use in Canada (Environment Canada, 2007), with the primary water uses being for irrigation, bathing and toilet flushing (Statistics Canada, 2010). Combined with personal transportation and emissions related to the production of goods consumed by households, home owners and tenants are responsible for close to half of Canada's total greenhouse gas emissions (Statistics Canada, 2008). Roughly 26% of the household contribution to total emissions is from residential fuel use and the production of electricity for use in the home (Statistics Canada, 2008).

Current market conditions are driving the adoption of advanced energy efficient technologies that not only reduce waste but also improve home comfort. The introduction of the new *Ontario Building Code* (OBC) format, including the *EnerGuide 80* alternative compliance option, has created renewed interest among builders and developers in higher performance mechanical systems. Higher efficiency standards, consumer awareness, and a pending increase in the Energy Star® compliance levels, have improved the quality of insulation being installed in production housing. Leaders in the residential construction sector are also recognizing that being able to offer renewable energy and advanced mechanical systems can distinguish them from the competition.

Sustainable home demonstration projects are crucial to building upon the current momentum in the home building market towards higher energy efficiency and environmental performance. They provide opportunities to educate both producers and consumers about sustainable and healthy alternatives to conventional home design, building materials and practices. They also facilitate monitoring and research on the performance and net benefits of these alternative designs and technologies in real world contexts.

Constructed in the summer of 2008, the Archetype Sustainable House is a semi-detached duplex designed to serve as a model or prototype for the next generation of "green" production homes. Like previous demonstration houses, the Archetype Sustainable House was created to showcase the best in

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[4] Secondary energy is energy used by final consumers for residential, agricultural, commercial, industrial, and transportation purposes. It does not include intermediate uses of energy for transforming one energy form to another (e.g., natural gas to electricity) or transporting energy to market (e.g., fuel for gas pipeline compressors).

sustainable design and technology. It was initiated with a national competition conducted in partnership with the Design Exchange. The intent of the competition was to engage architects, engineers and graduate students from across Canada to design a mass production green home for new community development. A comprehensive report was provided with each design submission, with final design drawings and specifications generated by the winning team prior to construction. On June 21, 2006, the winning design submitted by the Building Blocks Partnership was selected from 17 entries by a blue ribbon panel of judges.

1.2 Other sustainable housing projects

Over the years, there have been several sustainable home demonstrations in Canada. Some of the earliest demonstrations emerged out of the R-2000 initiative developed in the early 1980s by Natural Resources Canada's Office of Energy Efficiency in partnership with the Canadian Home Builder's Association. The aim of the initiative was to promote the use of building practices and technologies that were both energy efficient and cost effective by creating a system for certifying and building homes to an energy efficiency standard well beyond that required by building codes. Other rating and certification systems for green buildings have since emerged, such as the Leadership in Energy and Environmental Design (LEED) and Green Globes, both of which are based on achieving a series of credits in a variety of 'sustainability' categories.

In 1991, Natural Resources Canada launched the Advanced Homes Program to help develop and test innovative methods of reducing energy consumption, provide better indoor environments and reduce the environmental impact of houses. In all, ten different advanced houses were built across Canada with the goal of reducing energy demand to half of that of a typical R-2000 home and one quarter of the energy and half the water demand of a conventional Canadian home (NRCan, 2009a). During 1993, they were open to the public for a one-year demonstration period. They were then sold and, once occupied, monitored for at least one year to evaluate their performance.

In Toronto, perhaps the most widely known sustainable home demonstration has been the Healthy House, sponsored by Canada Mortgage and Housing Corporation (CMHC). A 1700 square foot semi-detached duplex Healthy House was constructed in the neighbourhood of Riverdale in Toronto in 1996. The builder lived in one of the units, and the other was rented by CMHC for 10 months to allow people to tour the house and learn about its many innovative features. The house was designed to be entirely self-sufficient, relying on passive and active solar technologies for heating, with no connections to gas, electricity, water supply or wastewater sewer infrastructure. Water supplies are provided entirely by rainwater harvesting and grey water recycling. Although the house is no longer open to the public, it continues to serve as an important example of how buildings can be self-sustaining.

The Canadian Centre for Housing Technology (CCHT) has developed the Twin Research Houses in Ottawa (CCHT, 2004). They are side-by-side, identical houses that were built in 1998 to facilitate evaluation of various advanced mechanical system technologies such as heating, ventilation and air conditioning (HVAC) and combined heat and power (CHP) cogeneration systems in a real world application. One house is maintained exactly the same over time as a baseline while advanced technologies are tested in its twin house, allowing researchers to accurately assess energy and cost savings. Each house is built to the R-2000 standard and has approximately 210 m^2 of heated floor area. Both houses are equipped with electronic controls that simulate occupancy by a family of four, thereby eliminating the potential for differences in energy performance related to different practices and lifestyles of the occupants.

The Factor 9 Home, completed in 2007, is a demonstration of a detached single family residence in Regina, Saskatchewan. To deal with Regina's continental climate, the home features very high levels of energy and water efficiency and environmental performance, aiming to produce 90% less greenhouse gas emissions than a typical Regina home (Dumont, 2007). The 301 m^2 house was designed to use nine times less energy per square metre of floor area and half the purchased water consumption of conventional homes in Saskatchewan. The house features an energy conserving envelope, orientation for passive solar heating, photovoltaic panels for active solar space and water heating, heat recovery ventilation system, drain water heat recovery, a ground source heat pump for space cooling and a rainwater harvesting system for toilet flushing and irrigation. Energy and water use and indoor air quality were monitored for a full year between 2007 and 2008 to evaluate the performance of the house in relation to the design objectives (CMHC, 2009).

Another major program that is underway is the EQuilibrium™ Sustainable Housing Demonstration Initiative led by the Canadian Mortgage and Housing Corporation (CMHC). It brings the private and public sectors across Canada together to develop homes and eventually communities that are models for sustainable design and living (CMHC, 2008a). In 2006, CMHC invited builders and developers to submit their ideas for housing that is healthy, affordable, sustainable and highly energy efficient. A total of 15 sustainable home demonstrations are being built and monitored through collaboration with teams of private designers and builders. EQuilibrium™ homes are designed to address occupant heath and comfort, energy efficiency and renewable energy production, resource conservation, reduced environmental impact and affordability (CMHC, 2008b). Once the demonstration homes are complete they will be open for public and professional tours for a minimum of six months. After the demonstration period, the homes will be sold and a performance monitoring period will commence for a minimum of one year. Monitoring will evaluate whether the homes meet design objectives such as net zero energy consumption (i.e., home produces as much energy as it consumes annually). EQuilibrium™ demonstration homes that may be comparable with the Archetype Sustainable House include:

- the Riverdale NetZero Project in Edmonton, Alberta (semi-detached duplex);
- the Abondance Montréal Project in Verdun, Quebec (triplex multi-family residence);
- the EcoTerra House in Eastman, Quebec (detatched single family house);
- the Alstonvale Net Zero House in Hudson, Quebec (detached single family house);
- the Avalon Discovery 3 House in Red Deer, Alberta (detached single family home); and
- the Inspiration Minto Ecohome in Ottawa, Ontario (detached single family home).

Other sustainable home demonstration projects are underway concurrently with the Archetype Sustainable House project that provide opportunities to compare performance monitoring results between sustainable home designs that are roughly equivalent in heated floor space and located in similar climatic regions.

1.3 Project purpose

The project was initiated to demonstrate sustainable housing technologies, materials and practices and ultimately, to influence how production homes are designed, built and lived so that ecological footprints are minimized and people's quality of life is improved. The house provides a learning facility for trades, builders, students and homeowners and a research laboratory for universities, colleges and private industry. Monitoring of the various innovative technology component systems in the two units of the duplex house will provide valuable insight into their effectiveness in the southern Ontario climate.

Unlike other sustainable house demonstration projects, the Archetype Sustainable House will remain open to the public indefinitely, serving as an ongoing education and training centre for builders, colleges, universities, and the public. The house and its many features will be monitored intensively to verify that technologies are performing as intended, and to serve as basis for improving on technology designs as may be necessary.

To date, the Archetype Sustainable Houses have been instrumented with over 300 sensors and a state-of-the-art National Instruments data acquisition system to allow the buildings and their various component systems to be monitored and evaluated continuously for research and educational purposes. Existing technologies and systems will be updated and replaced as new more effective products and ideas are developed to foster a process of ongoing learning and improvement. Several researchers and industry partners from different disciplines have been invited to conduct research in the houses. The multi-disciplinary nature of this work will, it is hoped, present opportunities for collaboration and knowledge sharing that will spark new ideas and forge pathways for creativity and innovation.

This first report provides a summary of the green features and innovative technologies installed in the houses. It also details the process of developing and installing a system of sensors and data acquisition hardware and software for monitoring of energy performance.

2.0 THE SITE

The twin houses are located at the Living City Campus at Kortright in the City of Vaughan, roughly 15 km north of Toronto, Ontario (Figure 2.1). The Campus is a centre for education and research on sustainable technologies. The Archetype Sustainable House is one of several demonstrations located on a 1.6 km Power Trip Trail that provides education and opportunities for research on renewable energy, energy efficiency, wastewater treatment and sustainable building design.

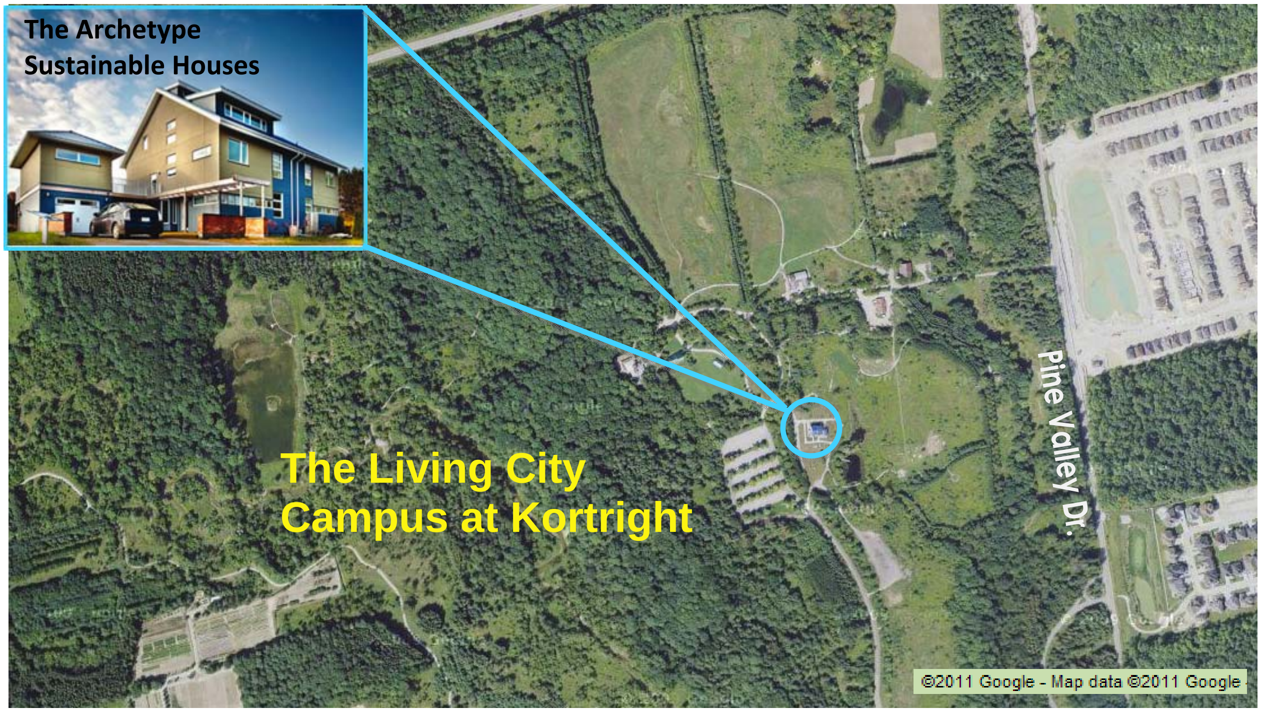

Figure 2.1: Location of the twin houses at The Living City Campus at Kortright.

The Living City Campus at Kortright is located on 250 hectares of pristine valley land located in the Humber River watershed. The site is approximately 25 km north of Lake Ontario, but not subject to lake effect weather patterns. Table 2.1 provides climate statistics for the area, based on 30 years of data collected at a North York weather station, roughly 10 km southeast of the site (Pelmorex Media, 2011).

Table 2.1: Climate statistics for the site, based on data from a North York weather station

Average annual temperature	8.4°C
Average annual rainfall	731 mm
Average annual snowfall	127 cm
Heating degree days	3788
Cooling degree days	306

The potable water for the Campus is pumped from wells located on the property. All wastewater generated at buildings on the campus is treated at on site facilities, and thus there is no connection to municipal wastewater infrastructure.

3.0 HOUSE DESIGN

The TRCA Archetype Sustainable Houses are a model for the next generation of green home design. Showcasing sustainable technologies, materials and practices, and promoting a holistic approach to home and community building, these demonstration homes provide both a detailed learning facility for trades, builders, students and homeowners to learn about sustainable housing, and a research facility for universities, colleges and innovative companies.

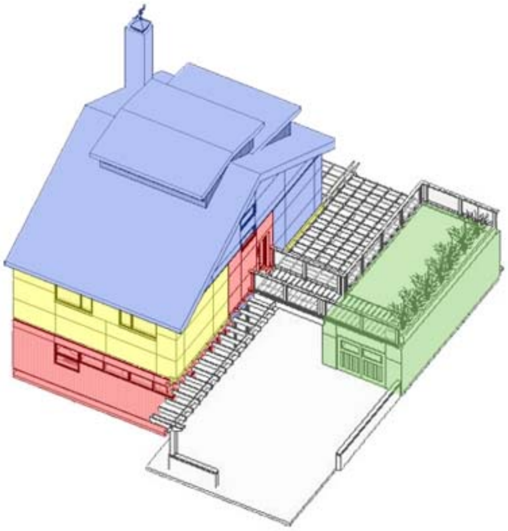

Figure 3.1: Building Blocks design, winner of the Archetype Sustainable House competition

The Archetype House is a semi-detached twin-house (Figure 3.2). House A is intended to demonstrate practices and technologies that are current and practical today. House B demonstrates practices in the near future. A Guest Suite is built above the garage of House B.

Figure 3.2: Archetype semi-detached twin houses A (right) and B (left)

3.1 Design concept

The design of the twin houses is the result of a national competition conducted by the TRCA and the Design Exchange. The challenge was to design a single family home to demonstrate the best in environmentally sustainable design and be a model for housing development in the GTA and beyond.

The winning design entry - called Building Blocks (Figure 3.1) - was a collaborative effort of three design firms,[5] recognizing an important connection of the home and neighborhood to quality of life. Homes can be tailored to each household, and are intended to foster real connections with nature.

The design is targeted at the production home-building market and the suburban home buyer. It has been third party certified as a LEED-platinum building – the highest rating possible in the LEED green building rating system. The building design includes wiring and monitoring equipment that will yield hard data regarding the performance of the energy and water conservation systems.

At the neighbourhood scale, stacks of blocks can be combined in pairs (semi-detached houses), rows (row houses or stacked townhouses) or slotted in between existing buildings (urban infill) to create diverse and interesting communities (Figure 3.3).

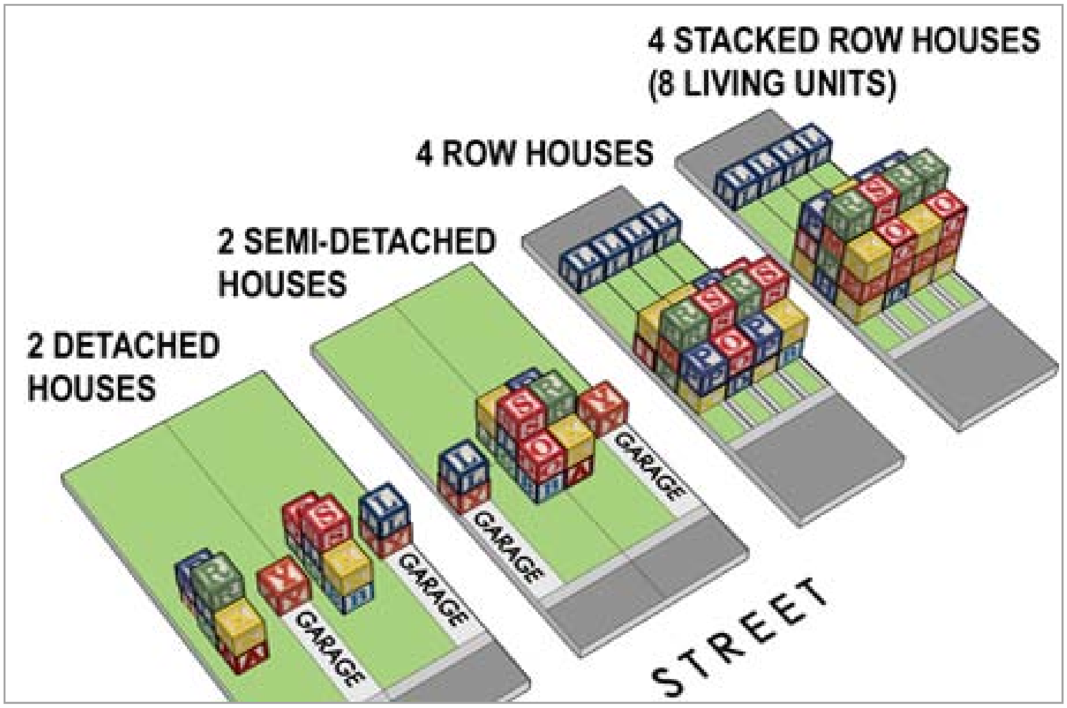

Figure 3.3: Four home types in Building Blocks concept (Wong and Stevens, 2009)

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[5] Fort Architect Inc., Lori Architects, and Stone's Throw Design

3.2 Key features

A commercializable design with advantages for both builders and homebuyers increases market uptake and the "mainstreaming" of sustainable design. Inside, the homes are spacious, snug and well-lit; outside, they have trellised courtyards, patios and green roofs. The following are some of the most important features of this unique design concept.

Modularity. Modular building blocks (Figure 3.4) give home builders and buyers a range of design options without the high cost of customization. The modular design creates economies of scale and efficiencies in the construction process, adapts to both field and factory production, and improves affordability. Four different housing types provide versatility to suit different lifestyles: detached, semi, row and townhouses from 2-7 bedrooms. This gives developers access to a greater pool of potential buyers, while giving homebuyers greater choice.

Adaptability/Affordability. An attached garage and fully finished attic (Figure 3.5) offers adaptable use with potential for rental income. Options include the number and arrangement of building modules, as well as finishes: renovation-ready attic vs. finished 3rd floor.

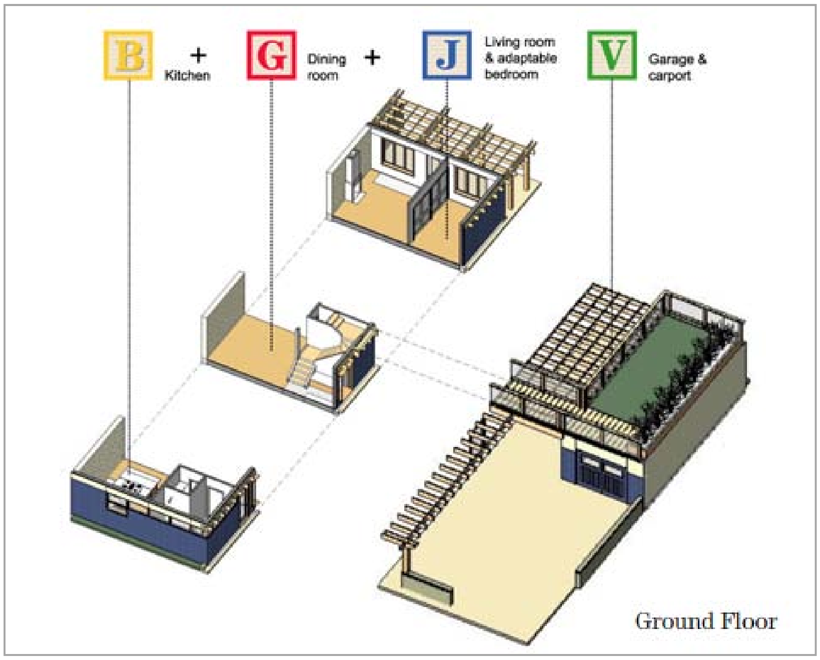

Figure 3.4: Building Blocks modules (Wong and Stevens, 2009)

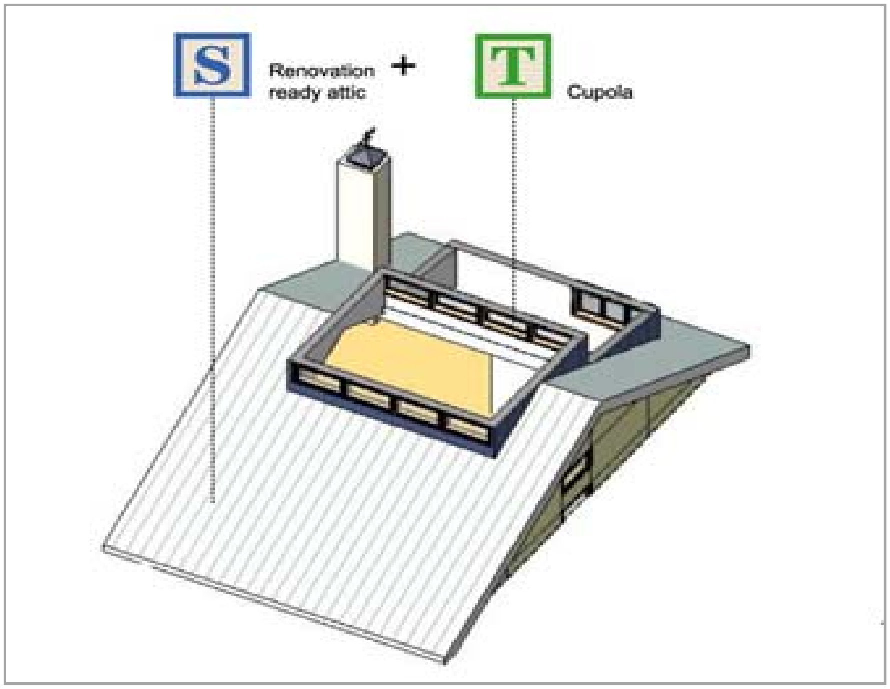

Figure 3.5: Renovation-ready insulated attic with cupola (Wong and Stevens, 2009)

LEED and Energy Star Certified. Third party environmental certification verifies best building practices. This reduces the home's environmental footprint with added benefits of energy bill savings. LEED is a point-based certification standard that recognizes the Sustainable House's many environmental features, including evacuated tube and flat plate solar hot water collectors, cedar pergola and planting for summer shading, composite wood decking, FSC glulam beams, engineered bamboo flooring, pergola carport between house and garage, EIFS stucco and FSC wood siding finish, reclaimed FSC wood cabinets, Energy Star appliances, LED lighting, recycled glass countertops, south facing windows for passive heating and light, and a passive solar glazing on the south façade.

Superior Insulation and Air-Tightness. The Sustainable Archetype House offers year-round comfort and low utility bills by means of high-grade insulation and a secure building envelope. Improved insulation and air-tightness also reduces mechanical equipment cost and warranty calls due to moisture damage.

Interior Design. The house's open concept design makes the most of natural light and air flow. An oak staircase made from recycled woods waste allows daylight to enter right into the centre of the Sustainable House, as well as creating natural "stack effect" ventilation.[6] The kitchen (Figure 3.6) features recycled plastic and paper countertops, energy-efficient appliances, and low flow plumbing fixtures. The spacious master bedroom includes an en-suite bathroom (Figure 3.7) with durable ceramic tile wall finish.

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[6] The "stack effect" is the movement of air into and out of buildings, chimneys, flue gas stacks, and so on, which is driven by buoyancy. Buoyancy occurs due to a difference in air density resulting from temperature and moisture differences.

Figure 3.6: Open-concept kitchen

Figure 3.7: Master bedroom en-suite bath

3.3 Selection of technologies

As part of the design of the Archetype Houses, various options were considered for the mechanical systems to be installed for ventilation, space conditioning and water heating. There were 17 cases evaluated in total, and each case (or unique combination of systems) was evaluated based on various criteria, including energy consumption, greenhouse gas emissions, EnerGuide house rating, and costs (i.e. gas and electricity costs, capital costs and life cycle costs) (Fung et al., 2009a). One of the 17 cases was a base case used for comparison. The base case was based on the Ontario Building Code minimum standards for a semi-detached dwelling, with some modification in building envelope and for an air conditioning unit with a higher SEER (Seasonal Energy Efficiency Ratio) of 14 rather than the minimum of 13.

Natural Resources Canada's HOT2000 and RETScreen software tools were used to simulate all cases and calculate energy consumption. Costs and greenhouse gas emissions were then calculated based on the electricity and gas consumption outputs from the simulation software. In order to use the consumption and cost data to compare the cases and determine the best combination of technologies, Dr. Alan Fung of Ryerson University developed a Computational Decision Making Matrix in which each factor that was to be considered (e.g. energy consumption, GHG emissions, EnerGuide house rating, annual energy costs, capital and life cycle costs, payback period) could be weighted according to its importance. In the scoring system, each factor of importance was given a weight between 0 and 100.

All the scores were linearly scaled between zero and the maximum weight one could assign to the factor based on the maximum and minimum values of that factor. For example, if a 20% weight was assigned for annual energy consumption, and the minimum and maximum outcomes for energy consumption were 50 GJ and 200 GJ, then the combination of systems with the 200 GJ energy consumption would receive a weight of 0% while that with 50 GJ would be weighted as 20%. All the other cases with values between 50 and 200 GJ would be scored linearly. Ultimately a single numeric score between 0 and 100 is calculated for each case by summing all the factor scores, allowing the cases to be compared to one another.

3.4 Description of house systems

Each of the two houses has their own HVAC and water systems. A central design feature of the Archetype Sustainable Houses is the high level of integration between its various components. For example, House B uses a geothermal ground loop as both a heat source and heat sink. By integrating the geothermal system with the radiant floors and ventilation system, House B can regulate its temperature efficiently without burning gas.

The water systems are also highly integrated. While conventional homes use eaves troughs to channel rain water away from the house foundation and rely on heavily treated (chlorinated and fluoridated) water for all household uses, the Archetype Houses make use of rainwater for non-potable household needs, such as toilet flushing and gardening.

The house's HVAC and water equipment fall into the four major categories described in the following subsections; (i) HVAC systems, (ii) the water heating systems, (iii) the electricity generation systems, and (iv) the water systems. Figure 3.8 depicts the energy and ventilation systems in House B, with coloured lines used to show the flows of air, thermal energy and electricity through the house.

3.4.1 Heating, ventilation and air conditioning

Air leakage through windows, floors and chimneys is typically 8-10 times greater in conventional homes as compared to homes with the R-2000[7] standard (NRCan, 2009b). This low level of natural ventilation in R-2000 homes is insufficient to expel moisture and pollutants from the home during hot or windless periods. To address this, R-2000 homes use a Heat Recovery Ventilator (HRV) or Enthalpy Recovery Ventilator (ERV) to bring fresh, filtered outdoor air into the house while maintaining air balance by removing stale air from the kitchen and bathrooms where most of the humidity and odours occur.

Although both houses are built based on the R-2000 standard, there are a few differences in the insulation, windows and mechanical systems. To minimize redundancy only a diagram of House B is included, as it is the more complex of the twin houses. Differences between equipment used in each house are noted in the text.

Figure 3.8 shows the ventilation system and insulation components for House B, and Tables 3.1 and 3.2 list the makes, models and technical specifications of HVAC equipment in Houses A and B, respectively. There are two major components of the ventilation system: (i) the ERV (HRV in House A), labelled "J", and (ii) the Air Handling Unit (AHU), labelled "T". The ERV captures heat from the exhaust air to pre-heat incoming fresh air, thereby reducing the energy consumption of the AHU. A high efficiency ERV can capture as much as 70 to 80 percent of the combined sensible and latent heat in the exhaust air (NRCan, 2009b). The ERV in House B differs from the HRV in House A in that it can transfer a certain amount of moisture along with sensible heat, while the HRV only transfers the sensible heat.

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[7] The R-2000 Standard – administered by Natural Resources Canada – is an industry-endorsed technical performance standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction.

The AHU, which is integrated with an air-to-air heat pump, has a variable speed fan and supplies forced air to the zones above the basement for space heating and cooling. Insulation features include super-insulated walls, floors and roof (E), super-efficient windows and doors (F), and passive solar features such as deciduous trees and an ivy trellis that shade the house during summer months but lose their leaves in the winter to let light through. House A has double-paned windows with fibreglass frames, while House B uses triple glazed, argon-filled windows. The wall insulation in House A is Roxul Batt Fibre with 3 inch Styrofoam, while House B uses Heat Lock Soya Polyurethane foam and Icynene spray foam. Table 3.3 provides a summary of the envelope features of the twin houses.

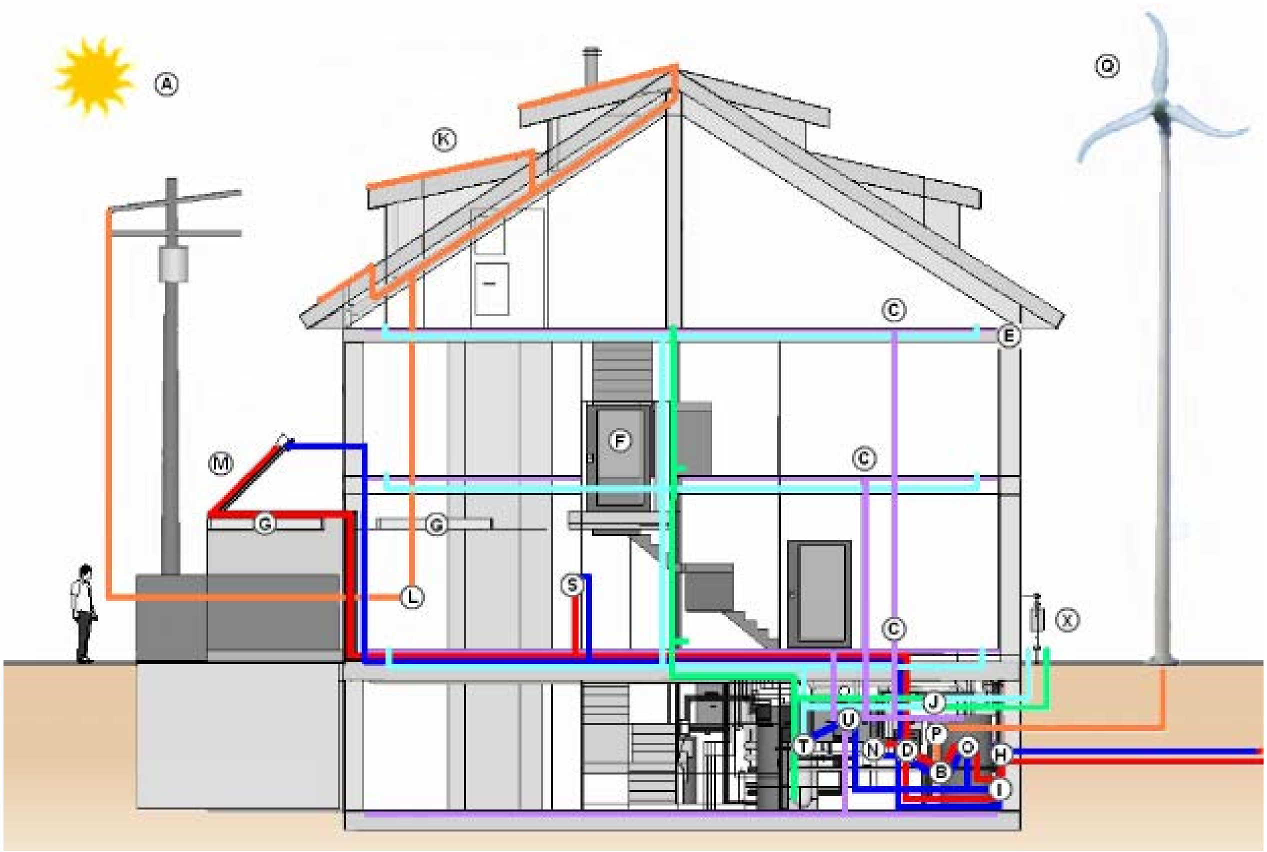

Fig. 3.8: Energy and ventilation systems of House B

Legend:

A - Sun
B - Cogeneration Unit
C - Radiant Floors
D - Thermal Storage Tank (Solar Hot Water Tank)
E - Super-insulated walls, floors, and roof
F - Super-efficient windows and doors
G - Ivy trellis and deciduous trees (passive solar)
H - Ground Loop
I - Ground Source Heat Pump desuperheater
J - Enthalpy Recovery Ventilator
K - Solar Photovoltaic Panels
L - Inverter
M - Solar thermal panels
N - Time of Use tank
O - Buffer tank
P - Electrical panel
Q - Wind turbine
S - Drain water heat recovery
T - Air handling unit
U - Climate control multifunction controller
V - Cistern
X - Gas meter

🟥 Heating medium
🟦 Cooling medium
🟪 Radiant floors
🟧 Electricity
▬ Air supply
🟩 Air return

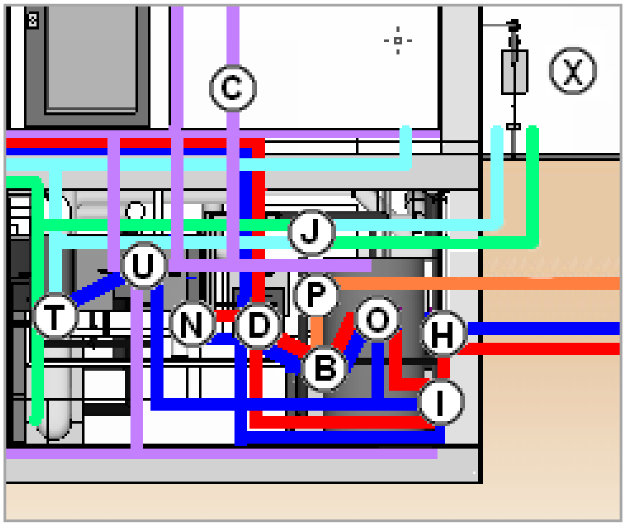

Table 3.1: Makes, models and technical specifications of HVAC and water heating equipment in House A

Equipment type	Manufacturer	Model	Specifications
Heat Recovery Ventilator	Venmar Ventilation Inc.	VanEE 3000HE	Surface area = 17.1 m^2 Net air flow rate = 198 m^3/h Sensible heat recovery efficiency = 74% at supply air temp of -25ºC
Air Source Heat pump with integrated air handling unit a) Heat pump b) Air Handling Unit	a) Mitsubishi Electric b) Advanced Distributor Products	a) PLA-A36BA, PUZ-HA36NHA b) BVRMB6230S3P3	Heat pump for heating: COP* = 3.45 Heating capacity = 11.06 kW at 8.3°C HSPF** = 9.4 Heat pump for cooling: Cooling capacity = 10.48 kW SEER*** = 16 EER*** = 17.6 Air Handling Unit: Cooling range max. = 565.72 L/s Heating range max. = 565.72 L/s Cooling capacity = 8.73 kW Water heating capacity = 16.73 kW at 377.14 L/s and 82.2°C entering water temperature
Drain Water Heat Exchanger	RenewABILITY Energy Inc.	R3-36	Length = 36 cm, diameter = 7.6 cm
Wall-mounted mini boiler	VIESSMANN Manufacturing Company Inc.	WB1A 8-24	Heating capacity = 18.46 kW
Domestic hot water tank	VIESSMANN Manufacturing Company Inc.	VITOCELL-B 100	Volume = 300 L
Flat plate solar collector	VIESSMANN Manufacturing Company Inc.	Vitosol 100 SV1	Gross area = 2.51 m^2, absorber area = 2.32 m^2

*COP = Coefficient of performance, the ratio of work or useful output to the amount of work or energy input

**HSPF = Heating Seasonal Performance Factor, a heat pump's estimated seasonal heating output in BTUs divided by the amount of energy that it consumes in watt-hours

***EER and SEER = Energy Efficiency Ratio and Seasonal Energy Efficiency Ratio. Both ratios represent cooling output in BTUs divided by the electric energy input in watt-hours. SEER differs in that it represents system efficiency over the entire season while EER is based on efficiency at a specific outdoor temperature.

Table 3.2: Makes, models and technical specifications of HVAC and water heating equipment in House B

Equipment	Company	Model	Specifications
Enthalpy recovery ventilator	Venmar Ventilation Inc.	VanEE 45808	Surface area = 14.51 m^2 Heating capacity (at -15°C supply air temp.) Sensible recovery efficiency = 55% Latent recovery moisture transfer = 0.26 Net air flow rate = 52 L/s Cooling capacity (at 35°C supply air temp.) Total recovery efficiency = 41% Net air flow rate = 50 L/s
Air handling unit	Ecologix Heating Technologies Inc.	C3-06	Max. heating capacity at 82°C entering Water temp. = 28 kW Cooling capacity = 1.5 - 3.5 tonnes Nominal air flow rate = 660 L/s
Drain water heat exchanger	RenewABILITY Energy Inc.	R3-36	Length = 91.44 cm, diameter = 7.62 cm
Solar hot water tank	VIESSMANN Mfg. Company Inc.	VITOCELL-B 100	Volume = 300 L
Evacuated tube solar collector	VIESSMANN Mfg. Company Inc.	Vitosol 300, SP3	Area = 2 m^2
Auxiliary hot water tank	GSW Water Heating	6G50SDE1	Volume = 175 L, Max. heating capacity = 3 kW
Buffer tank	GSW Water Heating	CST-80	Volume = 284 L
*Ground source heat pump	WaterFurnace International, Inc.	EW 042 R12SSA	Length of horizontal loop = 152.39 m Number of loops = 2 Depth of ground level = 1.52 m Heating capacity (at 0°C entering water temp. and 62.5 L/min water flow rate) = 13.3 kW Cooling capacity (at 25°C entering water temp. and 62.5 L/min water flow rate) = 12.66 kW, EER*** = 12.86
*Cogeneration system	Whispergen Limited	PPS24-ACLG-5	Electrical power =1 kW/230V, nominal thermal output = 7.0 kW
Photovoltaic cell	ARISE TECHNOLOGIES DEUTSCHLAND GmbH	MSK roof top 85 W modules.	Dimensions = 0.125 m x 0.125 m Capacity = 85 Wp/cell Module = 48 nos. Total capacity = 4.08 kWp

*Cogeneration system is a substitute for the ground source heat pump. These systems are not used simultaneously.

**EER = Energy Efficiency Ratio. Represents cooling output in BTUs divided by the electric energy input in watt-hours

Table 3.3: Envelope features of the twin houses

Feature	House-A	House-B	Guest Suite (House-B)
Basement walls	R-20 with Durisol blocks	R-20 with Durisol blocks	R-30
Walls	R-30	R-30	R-30
Wall insulation	Roxul Batt Fibre (R-21) + 3" Styrofoam	Heat-lock Soya Polyurethane Foam and Icynene spray foam	Heat-Lock Soya Polyurethane Foam and Icynene spray foam
Windows	0.28 $Btu/hr \cdot ft^2 \cdot {}^oF$ and double paned, low "E", fiberglass framed	All triple glazed, low "E" , with argon filled	No window
Roof	R40 Structurally Insulated Panels, which are insulated Styrofoam panels	R40 Structurally Insulated Panels, which are insulated Styrofoam panels	R40 Structurally Insulated Panels, which are insulated Styrofoam panels

Note: The R-value of an insulating material is a measure of the extent to which it resists heat flow. The higher the R-value, the more effective the insulator.

Within House B there is a separate living space, or "guest suite" which is connected to the house by a wooden platform. The unique HVAC feature of this suite is the solar wall which re-circulates sun-warmed air into the room. The suite has an integrated HRV and AHU unit for ventilation (Table 3.4). The function of this integrated unit is to draw fresh air from outdoors into the HRV core so that the energy from the outgoing stale air is transferred to the incoming fresh air. The conditioned fresh air is then blended with the circulating air of the heating/cooling system and distributed to the living areas of the home through the supply ductwork.

Figure 3.9: Guest suite of House B (left) and close up of guest suite solar wall (right)

Table 3.4: Makes, models and specifications of HVAC equipment in guest suite of House B

Equipment	Company	Model	Specifications
Solar wall	Your Solar Home Inc.	SH1500-G	Surface area = 2.4 m^2 Maximum heat generating capacity at 49°C and 33.5 L/s air flow rate = 1.67 kWh
Air handler & HRV unit	Nu-Air Ventilation Systems Inc.	Enerboss 400C	Maximum air flow rate for both heating and cooling = 212.25 L/s

3.4.2 Water heating

Integrated space-water heating systems in each of the twin houses combine the functions of space and water heating, reducing capital cost for the equipment and increasing operating efficiency. The house diagram (representing House B) in Figure 3.8 shows energy flows through this integrated system. Summaries of the water heating equipment in Houses A and B, including makes, models, and specifications, are provided in Tables 3.1 and 3.2, respectively.

House A

A solar combi-system[8] with an active flat plate solar collector is used for domestic hot water heating, along with auxiliary gas heating. A wall-mounted mini boiler is used for auxiliary heating when the solar collector alone is not sufficient. The mini boiler also aids in space heating by supplying water for the radiant heating system in the basement. United States Pharmacopeia (USP) grade propylene glycol is used as a heat transfer medium between the solar collector and hot water storage tank. The hot water system of House A is a one-tank system, which serves as both a solar hot water and time-of-use tank.

Another important feature of the water heating system is the drain water heat recovery system. This involves a “power pipe” that coils around the main drain water pipe and recovers heat from the drain water (*e.g.* from showering or laundry).

House B

Like House A, House B has a solar combi-system with an auxiliary heat source, which in this case is electricity rather than gas. The solar combi-system uses an evacuated tube, rather than flat plate solar collector for water heating. The house uses a two-tank rather than one-tank system for the domestic hot water supply; one tank is the solar hot water preheat tank and the other is the time-of-use based electric hot water tank which receives additional heat from a ground source heat pump desuperheater[9]. Like House A, House B also has a drain water heat recovery system used for salvaging heat from grey water.

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[8] A solar combi-system is a solar heating system that provides space heating and cooling, and hot water. It is often linked to an auxiliary heat source, such as gas or geothermal.

[9] The desuperheater is a waste heat recovery device that recovers excess heat from the compressor of the GSHP and, in this case, transfers it to the domestic hot water supply.

The horizontally-buried closed loop ground source heat pump (GSHP) system at House B consists of two J-shaped horizontal loops that extend underground from the north foundation wall of the house and are connected to the heat pump unit in the basement. An alcohol-based solution that is several degrees colder than the outside soil is circulated by the heat pump's refrigeration system. The solution exchanges heat with the surrounding soil, not only absorbing heat, but also releasing heat to the soil. The GSHP supplies warm and chilled water to a buffer tank that is used for space heating and cooling through the radiant heating system described in the next paragraph. A micro cogeneration system with a Whispergen Stirling engine has also been installed and can simultaneously produce electricity and heat water for household use or space heating. The cogeneration system serves as a substitute for the GSHP, and was not operational until 2010. In December 2010, the GSHP was shut down to allow for performance monitoring of the cogeneration system, which has been operational since.

Hot water is also used for the radiant heating system used throughout House B. A buffer tank is used to store the water supply for the radiant heating system. There are two pieces of equipment that can supply hot water to the buffer tank: (i) the ground source heat pump and (ii) the Whispergen cogeneration system. During the summer, the buffer tank supplies chilled water to the AHU to cool down the incoming fresh air in the ventilation system.

3.4.3 Electricity generation and conservation

Of the two houses, only House B has systems for generating electricity. There are three systems connected to House B: (i) a solar photovoltaic (PV) array, (ii) a household-sized wind turbine, and (iii) the mircro cogenerator discussed in Section 3.4.2. These systems are depicted in Figure 3.8.

The PV system on House B has a total of 48 modules, each with an 85 watt capacity. The total array area is 31 m^2 and the generation capacity is 4.08 kWp. The maximum efficiency is 13% at standard test conditions (STC)[10]. Sixteen of the modules are located on the upper dormer at a tilt angle of 9.46°, twenty-four modules are on the lower dormer at an angle of 11.77° and the remaining eight are on the lower part of the roof at an angle of 33.69°. The modules are grid-tied through a single inverter.

Connected to the main electrical panel in House B is a 1.8 kW grid-tied wind turbine. The horizontal axis turbine has non-furling blades and is mounted on a 50 ft tilting monopole. It is net-metered, offsetting House B’s electrical bill by slowing down the electrical meter, and even turning the meter backwards during periods of low household electricity demand.

The micro cogeneration system of House B uses a Stirling engine powered by natural gas to generate electricity, while capturing “waste” heat from the generator for water heating.

Both Houses A and B have measures installed for conserving electricity, including Energy Star® appliances, which consume 15 to 50% less energy and water than standard models (NRCan, 2009c).

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[10] STC are 25°C, 1.5 air mass and solar irradiance of 1000 W/m^2

Aside from the substantial daylighting afforded by the design of the houses, all lighting consists of compact florescent bulbs, which consume less power and have a longer rated life.

3.4.4 Water systems

The Archetype Sustainable House contains several technologies to maximize efficient use of water, and minimize both stormwater runoff and the demand for municipal water supply. While there are significant differences between the water systems in the twin houses, some of the systems are connected so that an excess of water supply in one house will supplement the supply in the other.

House A

Green roof. A green roof (Figure 3.10) installed above the garage in House A provides an opportunity for significant retention of rainfall on the garage roof. The Soprema® system covers an area of 19 m^2 and consists of 180 mm of growing media planted with native vegetation, a polyethylene root barrier, an irrigation layer that serves as a water reservoir, and a drainage layer. On average the system retains approximately 50% of rainfall incident upon it. A monitoring study conducted on the green roof from 2009 to 2010 investigated phosphorus loads in green roof runoff and the effectiveness of an engineered media product for reducing runoff phosphorus levels. The study was completed as part of the Masters thesis of Eric Camm from the University of Waterloo (Camm, 2011).

Figure 3.10: Green roof above House A garage

Permeable pavement driveway. A permeable interlocking concrete pavement system has been installed as the driveway for House A (Fig. 3.11). The installation consists of an open-graded base course layer overlaid with high performance bedding (angular, washed limestone material), on which Oakstone interlocking concrete pavers were installed. The full system, including pavers, is 45 cm deep, and allows for full infiltration of rainfall through the pavement and base course and into the native soil.

Figure 3.11: Permeable interlocking concrete pavement driveway

Disconnected downspout. Downspouts draining water from the roof of House A are extended out and away from the foundation of the house towards the garden to demonstrate the proper method for disconnecting a downspout from the storm sewer system.

Grey water recycling. A Brac^{TM} system allows for the collection of grey water draining from both showers in House A. The water is collected in a 150 litre barrel, filtered, chlorinated and pumped out to supply water for toilet flushing.

House B

Rainwater harvesting system. All stormwater draining from the south side of the roof of House B and the roof of the in-law suite is conveyed to a rainwater harvesting system. Drainage around the footing of the house is also conveyed to the cistern via an external sump pump. The rainwater harvesting system consists of a 10,000 litre underground concrete cistern insulated with Styrofoam SM. Water collected in the cistern is filtered and pumped into House B for use in toilets, and also to the hose bibs of both houses. It also serves as a back-up supply of water for the grey water system in House A.

Rain barrel. A 170 litre rain barrel collects all stormwater runoff from north side of the roof of House B. When the barrel is at capacity it overflows to the garden.

Permeable pavement driveway. The permeable driveway at House B is a combination of two products – Grasspave and Gravelpave – distributed by Terrafix® Geosynthetics Inc. The systems are similar, with the exception that one is surfaced with sand and grass, and the other with gravel. The gravel surfacing is used for the specific area where the car is parked regularly, while the remaining low traffic area of the driveway is grass surfaced. The system consists of a granular base course overlaid with a proprietary plastic grid (92% void space) and filter fabric mat that provides load bearing strength. The system allows for full infiltration of rainfall through the pavement and base course and into the native soil. The system in this driveway will be replaced during the summer of 2011 with an interlocking concrete block system, similar the driveway of House A.

Common systems

Wetland wastewater treatment. Wastewater generated in both houses is treated using a wetland wastewater treatment system from which water is suitable for infiltration into the ground (Figure 3.12). Wastewater from all sinks and toilets in both houses is pumped into the system, which consists of a septic tank, two wetlands and a tile bed. The first step in the treatment process is the septic tank which contains anaerobic bacteria, allowing for anaerobic digestion of waste. Water then enters the first wetland, which re-circulates water from the bottom to the top. Within this first wetland there is aerobic digestion of waste, and carbon and nitrogen removal. The second wetland contains iron ore slag, which binds to phosphorus in the wastewater. Treated effluent from the system is pumped to the tile bed for infiltration.

Figure 3.12: Surface view of the wetland wastewater treatment cells

French drains. Around the footing of both houses are French drains, which consist of a trench backfilled with gravel. The drains promote rapid drainage, protect the foundation from moisture, and keep the basement dry. Drained water is conveyed to an external sump pump and augments the water supply in the rainwater harvesting cistern of House B.

Xeriscaping. The yards of both houses are planted with drought-tolerant, low maintenance native plants so as to minimize the need for irrigation while maintaining a healthy and aesthetically pleasing garden, even during summer heat waves. Landscaping around the houses will be re-done in the fall of 2011 to demonstrate alternative residential landscaping concepts designed to reduce runoff and conserve water.

Water efficient appliances and fixtures. Both houses contain appliances and fixtures that conserve water, including Energy Star® washers and dishwashers, low flow shower heads, dual flush low flow toilets, and water efficient aerators.

4.0 MONITORING PROGRAM

Monitoring of the technologies at the Archetype Sustainable Houses was initiated in 2008 and is being carried out to track and evaluate the performance of the energy, water, and ventilation systems of the twin houses. The following subsections describe only the energy and ventilation monitoring activities. Monitoring of the water systems will be initiated in 2012 and will include assessment of individual technologies (*e.g.* green roof, permeable pavement, rainwater harvesting system) and the cumulative stormwater management and water conservation benefits of all the systems.

As part of the energy monitoring program, a variety of sensors have been installed throughout the houses to measure and record: (i) thermal energy flow, (ii) air flow and humidity, (iii) water flow, and (iv) electricity. Outdoor meteorological conditions (*e.g.* solar radiation, wind speed) are measured simultaneously at a nearby meteorological station. All sensor data collected are logged and analyzed by a data acquisition system specifically developed for performance monitoring of the houses. Benchmark data from the Ontario Building Code, Natural Resources Canada and the U.S. Dept. of Energy's Building America program (Hendron, 2005) will serve as a basis for comparison with performance data collected from the houses.

The evaluation approach is derived from the main project objective – to assess the performance of the technologies installed. To this end, the following specific objectives for the monitoring program have been defined:

- select, calibrate, and install sensors and data acquisition (DAQ) systems at locations of interest
- develop equations for evaluating individual mechanical systems
- develop a monitoring program in the LabVIEW software platform to collect and analyse data
- collect data (as raw signals and converted engineering units) in 5 second intervals hourly, stored in an SQL database with the capacity to conduct hourly, daily, monthly and yearly analysis of the stored data.
- evaluate thermal performance of the house in each season using data from the SQL database
- evaluate the hydronic system using supply and return water temperatures, and flow rate
- evaluate the mini-boiler, radiant floor system, and the ground source heat pump
- assess auxiliary energy use to assess the efficiency of components *i.e*. power consumption of major components such as heat pumps, cogeneration system, AHU, HRV/ERV, domestic hot water tank, pumps, fans, and grouped lighting and receptacles on each floor.
- determine the contribution of improved building envelope (e.g. insulation, windows) to the total energy savings for each house
- develop system modules in building simulation software with the monitoring data

4.1 Sensor selection and installation

Common input parameters for the Sustainable House monitoring equipment are air temperature, relative humidity, air flow rate/velocity, water temperature, water flow rate, power consumption, soil temperature and moisture, and solar radiation. These input parameters are used to determine the energy balance of the houses and the efficiency of each mechanical component. The parameters used for the evaluation are those defined in the ASHRAE standard.[11] In total there are over 300 sensors that have been installed in the twin houses. All sensor information is fed through a data acquisition system, where it is analyzed using a software package called LabVIEW.

Most of the sensors in the Archetype Sustainable House were installed at the time of construction, however some of the floor sensors were missed and needed to be installed after construction was complete. Sensors were installed according to manufacturer specifications to ensure that they would operate correctly and not be subject to any installation-related damage. For instance, air temperature and relative humidity sensors were located away from bended sections of ducts or fans for better accuracy.

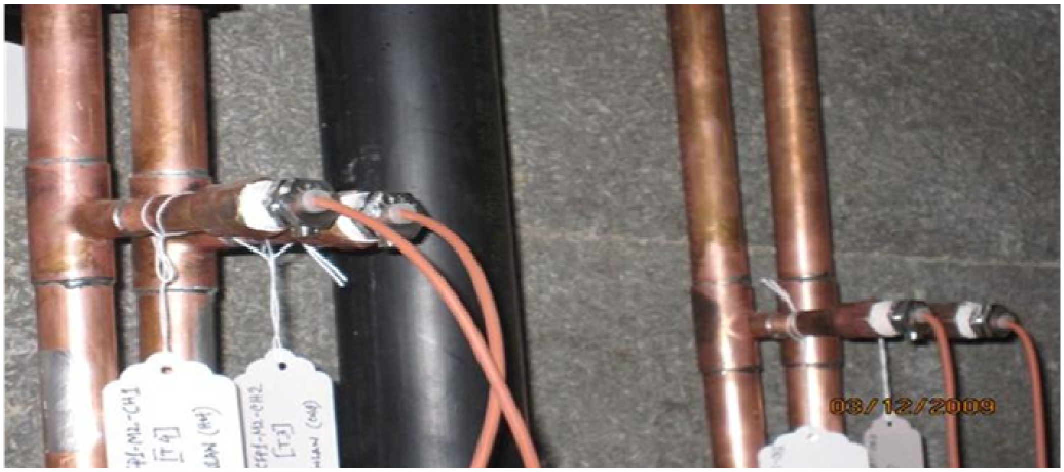

Figure 6.1: Matched pair of delta T sensors installed in the radiant floor heating system

4.2 Sensor calibration

All sensors were calibrated in order to identify and correct any systemic bias. The calibration methods used for the various sensors installed are summarized in Table 4.1.

Apart from the calibration of each sensor, error/uncertainty analysis was performed based on the sensor and calibrator accuracy specifications provided by the manufacturers. The calibration of sensors was carried out during initial installation but also has been and will continue to be a routine procedure throughout the monitoring study to ensure data quality.

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[11] The American Society of Heating, Refrigerating and Air-Conditioning Engineers develops standards for both its members and others professionally concerned with refrigeration processes and the design and maintenance of indoor environments. ASHRAE publishes the following three types of voluntary consensus standards: Method of Measurement or Test, Standard Design and Standard Practice.

Table 4.1: Methods used for calibration of sensors

Sensor	Calibrator
Resistance Temperature Detector (RTD) sensors	• HART Scientific series 9102S Handheld Dry-wells • MICROCAL 20DPC • Omega series CL3515R
Air temperature sensors	• MICROCAL 20 DPC • Omega series CL3515R
Air flow station and pressure transducers	• MICROCAL 20 DPC • Hot-wire Thermo-Anemometer (model: Mini air HW PRO-VT50)
Turbine type water flow rate sensors	Volume bucket and stopwatch (NIST, 2009)
PROTEUS series water flow rate sensors	Factory calibrated but cross-checked according to NIST guideline
Pyranometer	Factory calibrated (checked with against data from three other weather stations)
Wattnodes	Factory calibrated but cross-checked by power meter
Air velocity transmitter	Hot-wire Thermo-Anemometer (model: Mini air HW PRO-VT50)

4.2.1 Water temperature sensors

Three types of RTD temperature sensors are used for the measurement of liquid temperature: i) Pt-500 series immersed delta T RTD sensors, ii) Pt-100 series direct immersed RTD sensors and iii) Pt-100 series surface mounted temperature sensors. These sensors were calibrated using a handheld dry-well, a device that maintains the desired temperature settings within it, thus allowing for comparison between the device and the reading from the temperature sensors inserted into it. The device consists of a temperature controlled mass (such as a metal block) that generates a constant temperature environment. Holes drilled into the block allow for insertion of temperature sensors. With the help of the calibrator, all 26 Pt-500 and 16 Pt-100 immersed type temperature sensors were calibrated from a set point of 0°C to 90°C in 10° intervals. The offset values of each RTD sensor were then inputted into the data acquisition system.

4.2.2 Air temperature sensors

Air temperature sensors were calibrated with a Pt-100 surface mounted temperature sensor that had been previously calibrated through the method described in the previous section. During calibration, the tips of both sensors were placed adjacent to one another and the air temperature sensor readings were taken from the LabVIEW program. The referenced sensor reading was taken from the MICROCAL 20DPC calibrator. Using this method, more readings could be collected, allowing for greater accuracy.

4.2.3 Pressure transducers

All pressure transducers are coupled with flow stations to measure the volumetric air flow rate. The calibration was carried out in two steps. First, the pressure transducer was calibrated by the MICROCAL 20 DPC calibrator and Ammeter for milliamperes (mA) signals. The pressure transducer output range from 4 to 20 mA corresponds to a range of 0 to 1 inch of water column. The lowest output signal of each sensor was measured and a linear equation was obtained within the calibration range. For the corresponding flow station, there is a designed correlation between the pressure drop (inch of water column) and the volumetric flow rate. By multiplying this correlation with the linear correlation obtained in the first step, a polynomial equation of degree 7 was developed to accurately interpolate the mA signal into cubic feet per minute (cfm) for the corresponding duct size. Second, a hot-wire thermo-30 anemometer was used to measure the local air velocities at various positions over the cross-sectional area while a specific air flow rate was maintained in the duct. The local velocities were averaged and multiplied by the cross sectional area of the duct to get the actual volumetric flow rate. This flow rate was then compared with the value calculated from the polynomial equation to get the offset readings from the combined pressure transducer and the flow station. These steps were repeated three times for each flow rate to find the average offset reading.

4.2.4 Water flow meters

The calibration of this sensor was carried out according to the National Institute of Standards and Technology guideline (NIST, 2009). Water flowing through the sensor was collected in a volume bucket within a fixed period of time and then compared with the sensor data recorded for the same time period in the data acquisition system. This procedure was repeated three times for accuracy.

4.3 Data collection

Monitoring data has been collected for six pieces of equipment in House A and nine in House B. The parameters monitored from each are listed in Tables 4.2 and 4.3. Equipment diagrams are shown in Figures 4.3 to 4.9. Figure 4.10 at the end of the section shows the location of sensors in House B.

Table 4.2: Parameters of interest and sensors installed for monitoring of equipment in House A

Equipment	Parameters of interest	Sensors / meters used
Wall-mounted mini boiler	Gas consumption	Gas meter
	Electricity consumption	Watt-hour meter
	Hot water generation	Flow rate sensor
	Boiler efficiency	Temperature and flow rate sensors
Domestic hot water tank	Water consumption	Flow rate sensor
	Hot water generated by solar energy	Flow rate sensor
	Hot water supplied by the boiler	Flow rate sensor
Heat recovery ventilator	Amount of heat recovery	Temperature, relative humidity and flow rate sensors
	Air flow	Air flow rate sensor
Flat plate solar collector	Heat supplied by propylene glycol*	Temperature and flow rate sensors
	Efficiency of collector (%)	Temperature and flow rate sensors, pyranometer
Drain water heat exchanger	Amount of heat recovery	Temperature, relative humidity and flow rate sensors
	Heat re-capturing effectiveness	Temperature and flow rate sensors
Air handling unit (AHU)	Heat supplied to AHU	Temperature and air flow rate sensors
	Energy delivered to zone by AHU	Temperature and air flow rate sensors (on each floor)
Radiant floors	Water temperature	Temperature sensor
	Water flow rate	Flow rate sensor
ASHP	Electricity consumption of pump	Watt-hour meter
	Inlet air temperature and flow rate	Temperature and air flow rate sensors
	Outlet air temperature and flow rate	Temperature and air flow rate sensors

*Propylene glycol is the heat transfer media in the solar loop. Its density and heat capacity change with temperature.

Table 4.3: Parameters of interest and sensors installed for monitoring of equipment in House B

Equipment	Parameters of interest	Sensors / meters used
Time-of-use tank	Daily load	Flow rate sensor
	Electricity consumption for backup hot water generation	Watt-hour meter
	Efficiency of tank (calculated based on power input)	Watt-hour meter
Domestic hot water tank	Water consumption	Flow rate sensor and turbine flow rate sensor
	Hot water generated by solar energy	Temperature and flow rate sensors
	Hot water generation	Temperature and flow rate sensors
Enthalpy recovery ventilator	Sensible heat recovery	Temperature and air flow rate sensors
	Latent heat recovery	Temperature, relative humidity, air flow rate sensors
Evacuated tube solar collector	Heat supplied by propylene glycol*	Temperature and flow rate sensors
	Efficiency of collector	Temperature and flow rate sensors, pyranometer
Drain water heat exchanger	Amount of heat recovery	Temperature, relative humidity and flow rate sensors
	Heat re-capturing effectiveness	Temperature and flow rate sensors
Air handling unit (AHU)	Heat supplied to AHU	Temperature and air flow rate sensors
	Energy delivered to zone by AHU	Temperature and air flow rate sensors (on each floor)
Solar wall	Rate of energy flow by ventilation of gap air	Temperature, relative humidity, air flow rate sensors
PV array	Efficiency (calculated from PV electrical output, solar irradiance)	Watt-hour meter, pyranometer
Radiant floors	Water temperature and flow rate	Temperature and flow rate sensors
Ground source heat pump	Soil temperature and moisture	Temperature and soil moisture sensors
	Temperature and flow rate of alcohol-based pump solution	Temperature and flow rate sensors
	Electricity consumption (to run heat and circulation pumps)	Watt-hour meter
	Heating output (based out output water temperature and flow rate)	Temperature and flow rate sensors
Cogeneration system	Electricity consumption and generation	Watt-hour meter
	Natural gas consumption (based on volumetric flow rate of natural gas)	Gas meter
	Inlet water temperature and flow rate	Temperature and flow rate sensors
	Heating output (based on output water temperature and flow rate)	Temperature and flow rate sensors

***** Propylene glycol is the heat transfer media in the solar loop. Its density and heat capacity change with temperature.

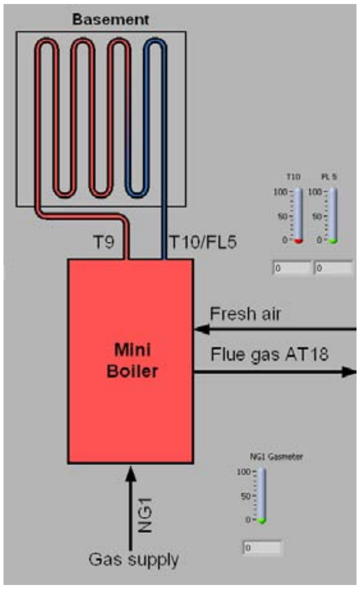

Figure 4.3: House A mini-boiler

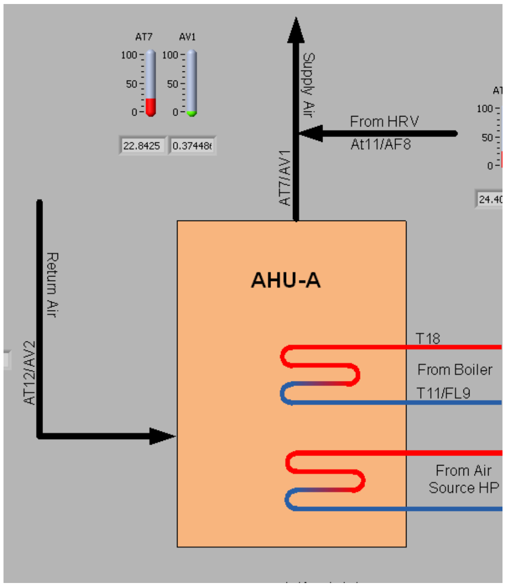

Figure 4.4: Air handling unit for House A

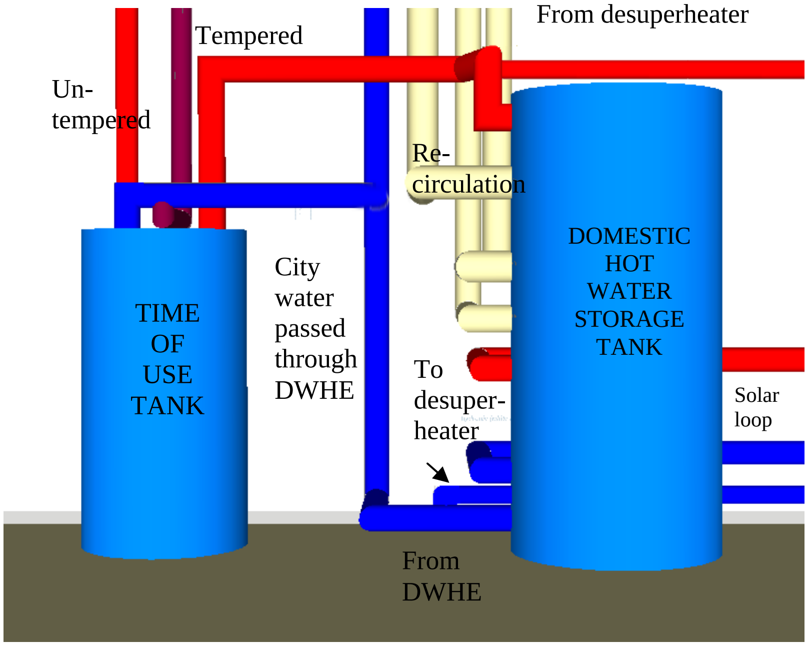

Figure 4.5: House B domestic hot water supply

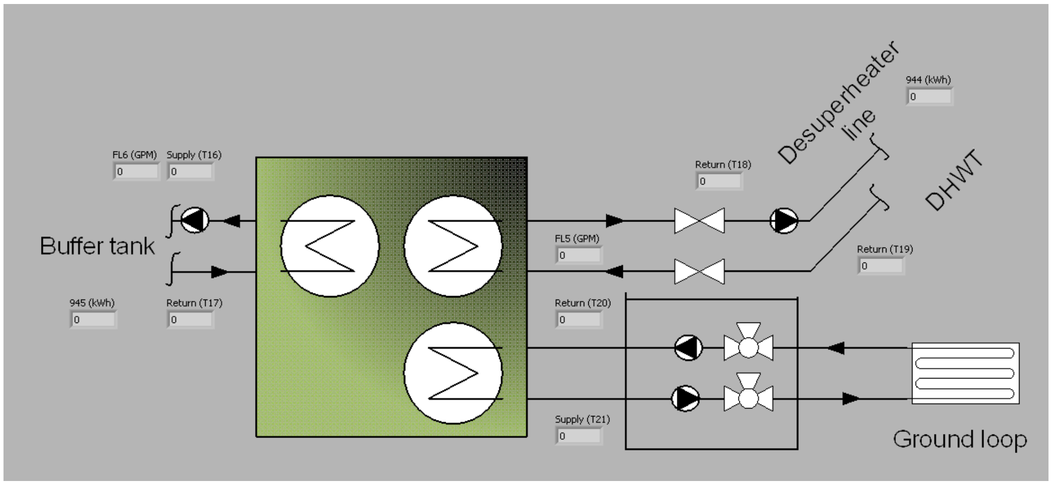

Figure 4.6: Schematic diagram of ground source heat pump connections

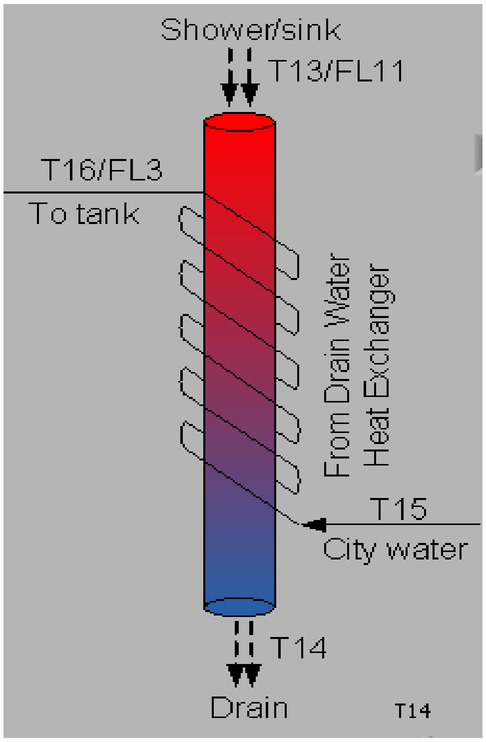

Figure 4.7: Drain Water Heat Exchanger

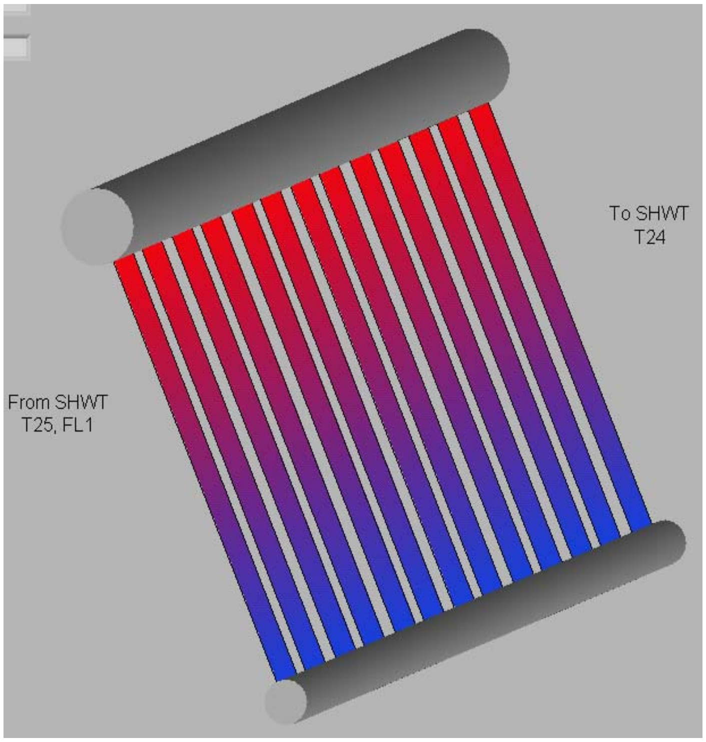

Figure 4.8: House B solar collector

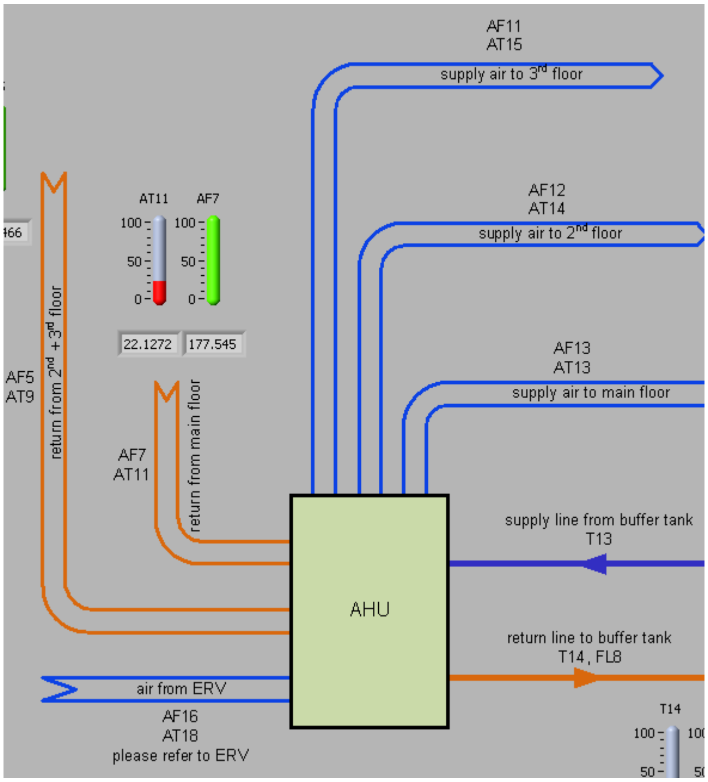

Figure 4.9: Diagram of House B AHU inflows and outflows

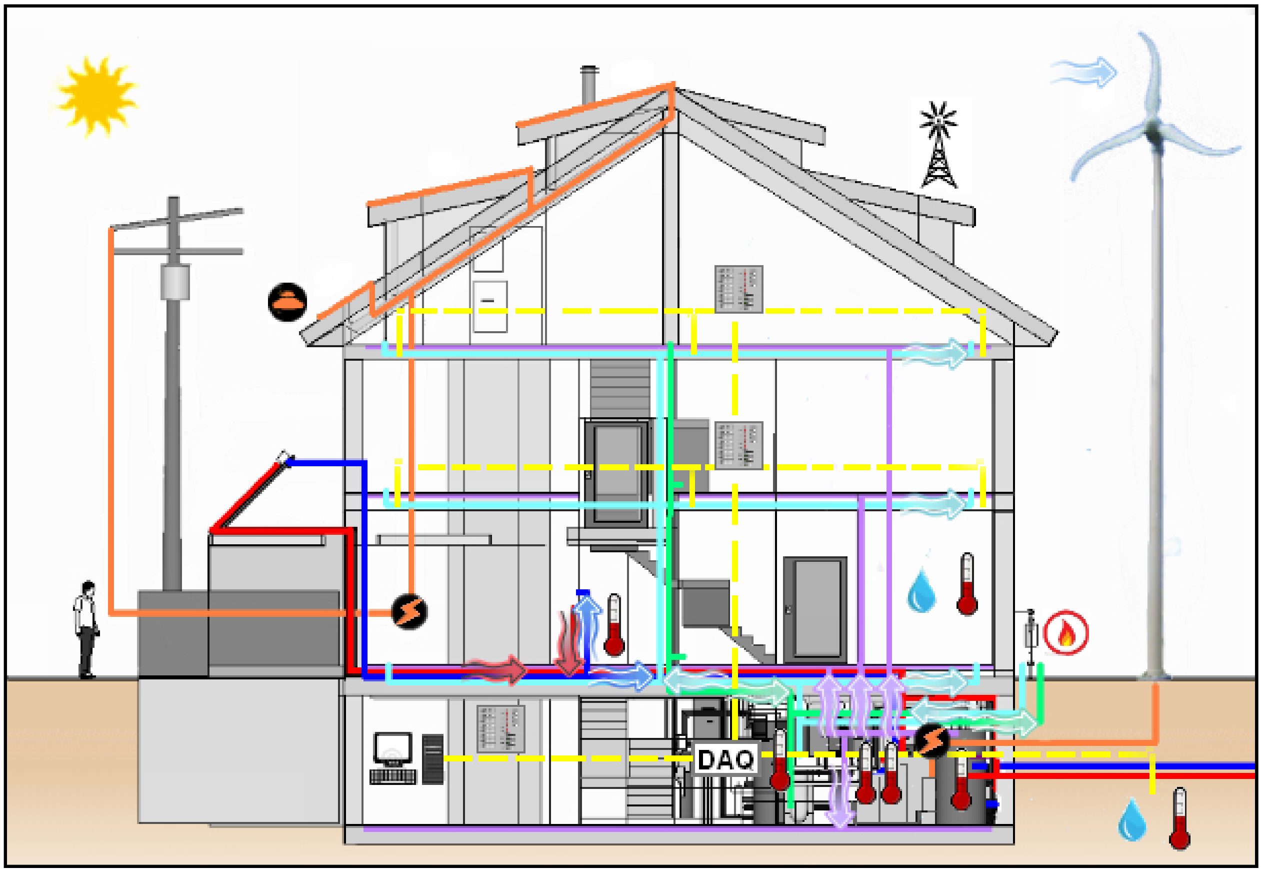

Figure 4.10: Monitoring of House B energy and ventilation systems

LEGEND

▦ Compact field point

⇒ Flow sensor (air, water, glycol)
Anemometer (wind)

🔥 Gas meter

● Pyranometer

💧 Relative humidity sensor (air)
Soil moisture sensor (ground)

🌡 Temperature sensor

⚡ Watt-hour sensor

▬ Electricity
▬ Heating medium
▬ Cooling medium
▬ Radiant floors
▬ Air supply
▬ Air return
- - Sensor cable

4.4 Development of the data acquisition system

Having identified the monitoring parameters of interest, the next step was to develop an adaptable, intelligent, real-time data acquisition (DAQ) interface. Attention was given to the integration of data acquisition and individual sensor calibration in the building envelope and mechanical systems. Extensive house wiring was necessary for the installation of an adaptable, intelligent, distributed DAQ system, which could produce good quality data with minimal noise. Compact Fieldpoint (cFP) systems from National Instruments were used in the DAQ system. The DAQ system consists of backplane, controller, module, connector block, power supplier, LabVIEW software platform and the computer. The selection of modules depends on the output signal of sensors. This output signal is converted into corresponding engineering units by the LabVIEW software (Table 4.4).

Table 4.4: Sensor names and output signals

Sensors Name	Output signal	Conversion unit
Flow rate sensor (liquid flow rate)	Pulse (Hz)	U.S. GPM
Direct immersed RTD probe	ohm	°C
Surface mounted RTD sensor	ohm	°C
Air temperature and Relative Humidity sensor	mA or V	°C and %
Pressure transducer with flow station	mA	ft^3/min
Air Velocity transmitter	mA	m/s
Gas meter	V	L/min
Wattnode	Pulse	Wh
Pyranometer (solar radiation)	mA	W/m^2
Soil Sensor (moisture content, temperature)	SDI-12	wfv (water fraction by volume) and °C

The central DAQ system is located in the mechanical room of the basement of each house, where the majority of the sensors are installed. In addition, each floor (except the main floor) has been equipped with a dedicated cFP to collect air temperature and floor temperature data. The guest suite of House B also has a dedicated cFP to process various signals, including a solar wall air heater.

Both low level parameters (*e.g.* temperature, flowrate, relative humidity) and high level information (e.g. efficiency, effectiveness, heat generation) can be displayed on the front panel of LabVIEW. Raw signals are converted and post-processed in the background. All signals are acquired at a constant sampling time of 5 seconds, with the exception of power consumption signals for which the sampling interval is 0.5 second. The software allows for adjustmest of sampling frequencies as needed based on data requirements. For the flowrate and power consumption, both the rate and total value are calculated. All data are stored directly in an SQL server.

4.5 Energy audit

An energy audit was conducted on the twin houses on December 16, 2009. The audit involved a depressurization test, a building energy simulation, and thermal images taken to identify potential locations of infiltrations, leakages, and thermal anomalies within the building envelope.

4.5.1 Depressurization test

Each of the twin houses was depressurized individually and simultaneously as a collective unit to measure the air tightness of the duplex. The south facing doors of the units were chosen to set up the blower door equipment. The fans were calibrated, and the indoor pressure was set to 50 Pascal (Pa). A total of 8 readings at intervals of 5 Pa were taken to measure the indoor pressure. The tests were conducted with outside temperature of -7.7°C and inside temperature of 20.0°C. Tables 4.5 and 4.6 show results of the individual and simultaneous depressurization tests. When the houses were tested individually air changes per hour (a measure of air tightness, with a lower value indicating a more airtight building) was similar in both houses. The ACH values were under 1.5 for both houses, which is considered very airtight and qualified for R2000 certification. As a comparison, and Energy Star home can have an air tightness value as high as 2.5 ACH@50pa, and the 2012 Ontario Building Code standard is 3.1 ACH@50pa.

Table 4.5: Air tightness results for individual testing of Houses A and B

Parameter	House A	House B
Net floor area (m^2)	345	350
Internal volume (m^3)	986	1036
Volumetric Flow rate (CFM)	698.5	665.0
Air changes/hour @50 Pa (ACH)	1.204	1.091

Table 4.6: Air tightness result for simultaneous testing of both houses

Parameter	Houses A and B
Internal volume (m^3)	2022
Volumetric Flow rate (CFM)	1363.5
Air changes/hour @50 Pa (ACH)	1.146

4.5.2 Thermal imagery

Thermal infrared imagery is a useful tool in performing non-destructive testing of a building envelope, revealing any problematic areas such as leaks around doors and windows, thermal bridging, and missing insulation. Indoor and outdoor thermal images were taken using a thermal infrared imager to identify locations of heat loss through the building envelope.

On the day images were taken, the outdoor temperature was -7.7°C with westerly winds of 15-20 km/h. Typical heat loss was seen through bridging in the envelope around studs, and leaks around windows and doors. Interestingly, one window in House B (second from the top in Figure 4.11) was found to be substantially warmer than its surrounding windows. The temperature of this second window was -5.5°C while the one above and below it were -9.6°C and -9.8°C, respectively. Since the same phenomenon was seen through both the interior and exterior, and since other windows in close proximity were present for comparison, it can be concluded with high confidence that the second window from the top on the east side of House B is deficient, likely due to lose of the argon gas within the glass panels.

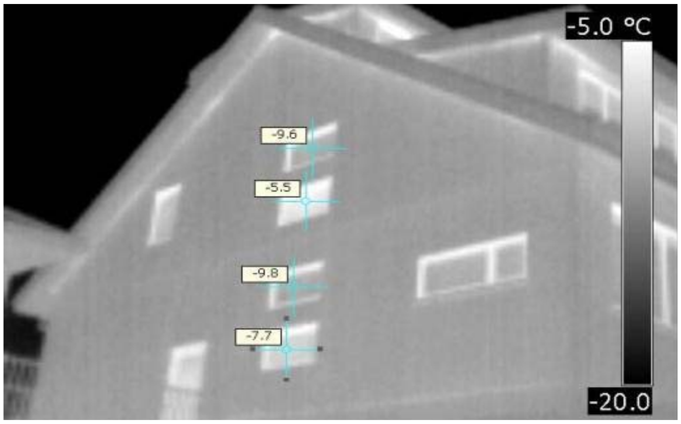

Figure 4.11: Thermal image of House B's east windows

4.5.3 Building energy simulation using HOT2000

Natural Resources Canada's HOT2000 version 10.50 software was used to evaluate the energy performance of the house. HOT2000 is a microcomputer program that has been validated using HERS BESTEST, and calculates the monthly and annual space heating requirements of the house, which must be provided by the heating system based on the input data such as weather conditions, building envelope configurations, thermostat schedules, infiltration rates, and heating and ventilation systems (Haltrecht et al., 1997; NRCan, 2010).

Based on parameters such as weather conditions, building envelope configurations, infiltration rates, and HVAC systems specifications, the annual energy consumption levels for the house were determined with HOT2000 (Table 4.7). According to the energy simulation results, House B performed better than House A. This is largely a result of more efficient mechanical equipment and a better insulated building envelope in House B. It was also determined that both houses were more energy efficient than the R-2000 building standard, which has significantly higher efficiency requirements than the current Ontario Building Code.

Table 4.7: Annual energy consumption levels of Houses A and B

Parameter	House A	House B
Heated floor area (m^2)	345	350
Space Heating (kWh)	9,438	4,497
Space Cooling (kWh)	2,147	1,272
DHW Heating (kWh)	1,834**	626**
Appliances and Lighting (kWh)	5,840	5,840
Total Energy (kWh)	19,259	12,235

Note: Due to HOT2000 limitations, Toronto's International Airport weather data was used for energy modeling.

** Includes grey water heat exchanger, solar thermal system and equipment efficiency.

When interpreting simulation results, it is important to be aware of the following limitations of the HOT2000 program. HOT2000 does not support user-defined operational schedule for lighting and appliances and therefore a year-round average for lighting and appliance load has to be assumed. Another limitation of using HOT2000 is the program's inability to simulate advanced building materials and mechanical equipment. Both houses use energy efficient materials and technologies that today are not yet common in house construction. The HOT2000 database is based on standard building materials and technologies and therefore some of the materials and technologies that are implemented in the Archetype Sustainable House could not be found in the HOT2000 database (Fung et al., 2009b).

For instance, House B is equipped with a ground-source heat pump, drain water heat recovery system, and solar-thermal collector. In order to simulate the energy performance of these systems using HOT2000, the input parameters were determined using alternative software (RETScreen) and then entered into HOT2000. For the grey water heat recovery system, the expected rise of city water temperature through grey water heat exchanger was determined. A medium water usage temperature of 41°C with 6°C drop from tap to drain was assumed. The average temperature rise of 10.4°C was used as the temperature differential for the reduction of supply hot water temperature. HOT2000 used 55°C as the default value for hot water load and therefore using the temperature difference of 10.4°C, a set point temperature of 44.6°C was assumed. Envelope materials such as bio-based insulated concrete forms in the below-grade wall and soy-based spray foam insulation in the above-grade walls are not included in the HOT2000 database and therefore these new materials have to be defined in the simulation model.

5.0 NEXT STEPS

The Archetype Sustainable Houses have been designed as a living laboratory for green building technologies. As evaluations of the systems originally installed in the houses are completed, the information obtained and lessons learned will provide valuable information on the effectiveness of the existing technologies, and potential areas of improvement. The following new technologies and strategies for optimizing performance are currently being considered for implementation in the twin houses:

- **Addition of ClimateWell® thermal cooling to the cogeneration system.** The ClimateWell® system is a chemical heat pump capable of using waste heat to generate cooling. The system has the ability to store energy and convert hot water to cooling or heating, without the consumption of electricity. The system can accept heat generated by solar thermal collectors or district heating, or waste heat from electrical generators or a cogeneration system. By adding a ClimateWell® thermal cooling system to the cogeneration system in House B, it becomes a trigeneration system, which is capable of harnessing the waste heat to simultaneously generate electricity, heat and cooling.

- **Installation of a Heart™ Transverter**. A transverter is an electrical power conversion device. It is capable of combining electrical power from various sources (e.g. solar panels, wind turbines, batteries, power grid) and converting power between different voltages and AC or DC. Once installed in the Archetype house, the battery bank in the transverter will serve as an internal uninterrupted power supply (UPS). This would allow the house to go temporarily off-grid in the event of a power outage, with the transverter acting as the grid. The transverter also has six programmable loads, so that lights and electrical devices can be switched on and off automatically based on a predetermined schedule. Lastly, the transverter can also improve power factor[12] on site, which means that electrical power is being used more effectively, and transmission losses to the grid are reduced. In Ontario, the financial benefit of a higher power factor is realized by electricity distribution companies, and also by individual owners of industrial, institutional and commercial buildings, for which the distribution company determines power factor for each site. Currently power factors are not assessed for residential buildings, which limits billing accuracy and represents a significant loss to the distribution company.

- **Installation of a Building Integrated Photovoltaic/Thermal (BIPV/T) collector to be coupled with a two-stage variable capacity air source heat pump (ASHP).** A BIPV/T collector consists of photovoltaic panels that form part of the building envelope (e.g. roof, facades, skylights), and which not only produce electricity but also recover thermal energy that can be used for space or water heating in the building. Heat from the back of the collector is recovered by a circulating fluid that absorbs the thermal energy. This also helps to cool the collector, thereby improving the efficiency with which it converts solar energy to electricity. The thermal energy generated by the BIPV/T collector will be used to improve the efficiency of the ASHP. Because the heat pump operates least efficiently when the

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[12] The ratio of actual power being used in a circuit (in units of watts or kilowatts) to that of the power being drawn from the power source, usually the power grid (in volt-amperes or kilovolt-amperes). The difference between the actual power being used and the power drawn from the source represents the amount of power that is lost and does no useful work. Power factor is typically expressed as a ratio between 0 and 1.

incoming air temperature is low, pre-heating the air entering the heat pump with the thermal energy from the collector will greatly increase its efficiency.

- **Improve landscape-based stormwater management**. The outside areas of the twin houses will be retrofitted with landscape measures to optimize absorbency and minimize stormwater runoff to the extent that the majority of rainfall events will not generate runoff. Added to the landscape measures already installed on site will be a rock garden, rain gardens, and herb and vegetable gardens to be constructed and planted in the fall of 2011. Monitoring of these 'absorbent landscape' measures will shed light on their effectiveness in combination and alone, the stormwater management and water conservation benefits they can provide, and their maintenance costs. Recommendations will be developed based upon monitoring data from this and other sites, as well as community scale implementation and demonstration projects being conducted in Brampton, Richmond Hill and Toronto through TRCA's Sustainable Neighbourhood Retrofit Action Plan (SNAP). Learning outcomes from the project will be shared within communities through the SNAP and also disseminated more broadly through presentations, tours and web communications in order to showcase the private and public benefits of these applying these alterative landscape measures in residential communities.

With respect to performance evaluation, monitoring of the houses and the individual systems within them will continue with a new emphasis on generating realistic energy and water consumption patterns. One means of obtaining an accurate assessment is to develop load profiles to simulate a family's energy and water consumption. In establishing an appropriate load profile it is important to consider that the houses are very different from an average home and the energy and water use patterns cannot be expected to be the same as those of an average home. Accurate consumption data may also be generated by allowing the twin houses to be occupied by residents for a fixed period of time. The residents (likely 4 per house) will be asked to carry out their usual lifestyle, including usual patterns of energy and water use. Data collected during this occupancy period, or when load profiles are applied, will provide valuable insight into how well the house systems perform when subject to real life consumption patterns. This will provide the basis for comparison to performance of other conventional or energy efficient homes.

Also planned in the near future is the posting of summary monitoring data (from the data acquisition system's LabVIEW software) on the web. The display data will be near real-time and available for viewing on in-house televisions by touring visitors as well as on existing websites affiliated with the Archetype Houses. These may include the main Archetype House website (www.sustainablehouse.ca), the Kortright website (www.kortright.org), the Sustainable Technologies Evaluation Program website (www.sustainabletechnologies.ca) and the Living City Campus website currently under development.

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