Living City Lab

The Living City® CAMPUS

www.thelivingcitycampus.com

Archetype Sustainable House

Constructed in 2008, the Archetype Sustainable House is a full-scale demonstration of the latest and most effective technologies and practices the market has to offer in the areas of energy efficiency and renewables, green building materials, water efficiency, and low impact development stormwater management.

This Living City Lab has been designed and constructed to demonstrate the feasibility of building homes that use less energy, water and natural resources, and generate less waste, while also being more comfortable and providing a healthier indoor environment for occupants.

The lab consists of twin houses; House A incorporates technologies that are practical in today's market, while House B showcases technologies that are more cutting edge and less available on the mass market. The facility is unique not only for the leading-edge technologies it houses, but also the extent to which its systems are interconnected. It is designed to allow many of the existing systems (e.g. heat pumps) to be switched out or bypassed in order to accommodate the varying requirements of research projects being conducted at this lab.

The Archetype Sustainable House project was initiated to educate and motivate the public and building industry professionals to move beyond these obstacles and to adopt greener building practices.
To view all past and present research at the Archetype Sustainable House visit https://thelivingcitycampus.com/labs/archetype-sustainable-house/.

ABOUT

Sustainable Technologies EVALUATION PROGRAM

STEP is a multi-agency program developed to help achieve the Living City Vision by accelerating adoption of sustainable technologies and practices.

STEP overseas and facilitates all research carried out at the Living City Labs located on the Campus, working with academic and industry partners to ensure research objectives are met.

STEP projects and initiatives, carried out at the Living City Campus are focused on:

- Monitoring and evaluating clean water and low carbon technologies;
- Assessing technology implementation barriers and opportunities;
- Developing supporting tools, guidelines and policies; and
- Advocating for and educating about effective sustainable technologies

Visit www.sustainabletechnologies.ca for more information.

DATA AQUISTION SYSTEM (DAQ)

The Archetype Sustainable House also houses a data acquisition system (DAQ), which receives data from the variou sensors in the House as well as from two other Living City Labs – the Photovoltaic and Wind Field Test Sites. (Table 1). Because requirements for data acquisition, monitoring, and control vary from one project to another, as do the platforms on which the research project is implemented, the DAQ developed is flexible, interoperable and platform-independent. It provides access to sensor data using web based services so the user is not limited to any particular operating system, platform, or programming language. With this system in place, Lab users can focus on their research without spending time and effort on the data acquisition portion of their project. Where necessary, STEP staff operating the Living City Labs can also provide custom code and libraries that can be used as templates in order to provide fine grained control of DAQ resources.

Table 1: DAQ System Specifications

Subsystem	# of Datapoints	Sampling Period (sec)	Sensor Types	Communication Protocols	Analog Data Resolution
House A	104	5	water temperature, water flow rate, air temp/humidity, boiler temp/humidity, load voltage, current, power (fridge, dryer, pumps etc)	MODBUS (Ethernet), RS-232, OPC	AI: 12 bits Thermocouple: 16 bits
House B	370	5	water temperature, water flow rate, air temp/humidity, boiler temp/humidity, load voltage, current, power (fridge, dryer, pumps etc), PV/Wind Generation voltage, current, power	MODBUS (Ethernet), RS-232, OPC	AI: 12 bits Thermocouple: 16 bits
PV Test Site	125	1	PV Panel voltage, current, temperature, irradiance, Inverter power, reactive power, Load voltage, current, power	MODBUS (Ethernet), RS-232, OPC, IEC 61850, DNP3	AI: 12 bits Thermocouple: 16 bits
PV Wind Site	58	5	Wind speed, Wind direction, Inverter power, reactive power, Load voltage, current, power	MODBUS (Ethernet), RS-232, OPC	AI: 12 bits Thermocouple: 16 bits

The backbone of the DAQ system is composed of four individual, distributed subsystems each of which is responsible for acquiring sensor data for a distinct geographical area. (Fig 1)

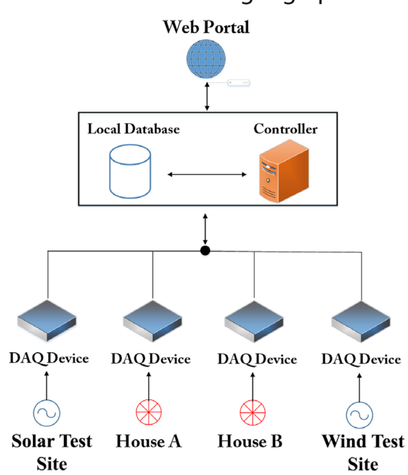

Figure 1

These subsystems collect data from:

- each of the twin houses (House A and House B),
- the PV test site, and
- the wind test site.

For these four areas combined, the DAQ collects data from over 500 individual monitoring points. At a configurable sampling rate, each individual subsystem acquires raw sensor data, applies the appropriate signal scaling for each output, and logs the data to disk in 10 minute intervals. It also broadcasts the latest values of all the sensor data over the network. The supervisory controller collects the data file from each distributed controller and stores it to the local database. It also subscribes to the broadcast provided by the subsystems, and publishes these values (in real-time) through its web portal to the rest of the network. The web portal is the main interface where researchers can request specific data points when using the Living City Labs. In addition to facilitating these requests, the Main Controller maintains feature-rich dashboards that allow users to visualize live and historical data in order to determine short and long term trends.

ENERGY SYSTEMS

A summary of the systems used for space heating and cooling, ventilation, water heating, and electricity generation in the twin Archetype Houses is provided in Table 2. Of the two houses, only House B has systems for generating electricity.

The following electricity generating systems are connected to House B:

- a 4 kW solar photovoltaic array;
- a 1.8 kW household-sized, grid-tied wind turbine; and
- a mircro cogeneration system using 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 also have measures installed for conserving energy. Electricity saving features include Energy Star® appliances, which consume 15 to 50% less energy and water than standard models (NRCan, 2009c). 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.

In order to minimize heat loss and reduce energy consumption for space heating, the Houses have been constructed with envelope features that provide superior insulation and air-tightness. These features are detailed in Table 3.

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. *(cont. P.4)*

Table 2: Makes, models and technical specifications of HVAC, water heating equipment and other energy systems in Archetype Houses.

House A			House B		
Equipment	**Manufacturer**	**Specifications**	**Equipment**	**Manufacturer**	**Specifications**
Heat Recovery Ventilator	Venmar Ventilation Inc.		Energy recovery ventilator	Venmar Ventilation Inc.	
Air source heat pump with air handling unit (AHU)*	Heat Pump: Mitshubishi Electric AHU: Advanced Distributor Products	3 ton nominal heating capacity	Mutli-zone air handling unit	Ecologix Heating Technol-ogies Inc.	3 heating zones
Drain Water Heat Exchanger	RenewABILITY Energy Inc.		Drain water heat exchanger	RenewABILITY Energy Inc.	
Wall-mounted mini boiler	VIESSMANN Manufacturing Company Inc.	Heating capacity = 18.46 kW	Air-source heat pump water heater	A.O.Smith	
Domestic hot water tank	VIESSMANN Manufacturing Company Inc.	Volume = 300 L	Solar hot water tank	VIESSMANN Mfg. Com-pany Inc.	Volume = 300 L
Flat plate solar collector	VIESSMANN Manufacturing Company Inc.	Gross area = 2.51 m2, absorber area = 2.32 m2	Evacuated tube solar collector	VIESSMANN Mfg. Com-pany Inc.	Area = 2 m2
Air-to-water heat pump	Mitsubishi Electric	Not yet on the market	Auxiliary hot water tank	GSW Water Heating	Volume = 175 L
			Buffer tank	GSW Water Heating	Volume = 284 L
			Ground Source Heat Pump**	WaterFurnace Interna-tional, Inc.	3.5 tons nominal heating capacity Both vertical and horizontal ground loops
			Cogeneration system**	Whispergen Limited	Electrical power =1 kW/230V, nomi-nal thermal output = 7.0 kW
			Low-temperature hydronic radiator with integrated HRV	Jaga	Heat exchanger efficiency > 80%
			Photovoltaic system	ARISE TECHNOLOGIES DEUTSCHLAND GmbH; Fronius	Total capacity = 4.08 kWp
			Wind turbine	Southwest Windpower	Total capacity = 1.8 kW
Electric car charger	Sun Country Highway	30A	Electric car charger	Tesla	

*Note that the air handling unit also contains a back-up hydronic heating coil. When back-up is required, heated water from the mini-boiler is circulated through the coil and heat is distributed through thouse using forced-air from the air handling unit. **Cogeneration system is a substitute for the ground source heat pump. These systems are not used simultaneously.

Table 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•ft2•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 insulat-ed 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.

House A

Green roof. A green roof 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 m2 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.

Permeable pavement driveway. A permeable interlocking concrete pavement system has been installed as the driveway for House A. 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.

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 BracTM 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. A permeable interlocking concrete pavement system has been installed as the driveway for House B. The installation consists of an open-graded base course layer overlaid with high performance bedding (angular, washed limestone material), on which Unilock ThornburyTM 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.

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.

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.

Interested in this Living City Lab?

There are various ways to get involved, including:

- using the laboratory to carry out research
- becoming a research partner
- donating products or services
- volunteering

Visit **https://thelivingcitycampus.com/get-involved/** to learn more about getting involved, and to access our online "Expression of Interest" form or contact us directly at: STEP@trca.on.ca.

The Living City Campus is an intiative of Toronto and Region Conservation (TRCA)

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