Earth Rangers educates children about biodiversity, conservation and adopting more sustainable behaviors. The nonprofit organization built the Earth Rangers Centre 10 minutes north of Toronto to reflect its core values of sustainability and to aim to be one of the most efficient buildings of its size in North America.

The 63,000 ft² Centre is home to 50 Animal Ambassadors (including a bald eagle and other birds of prey, a ring-tailed lemur, painted turtle and a ball python) and their respective habitats. The building is occupied 16 hours a day, including corporate facility rentals and volunteer events, building tours and technology testing. In addition, Earth Rangers leases space to tenants such as the Toronto and Region Conservation Authority.

It was designed to be 63% more efficient than Canada’s Model National Energy Code for Buildings (MNECB). The building opened in 2004 with a sound base of sustainable technologies such as thermal mass, a solar-ready roof, exposed concrete ceilings for radiant heating and cooling, ground coupled heat exchange for ventilation air in the form of earth tubes, bioswales, and an onsite wastewater treatment plant.

However, Earth Rangers wanted even better performance. The building underwent a $4.5 million renovation in 2010 of its mechanical and controls systems as well as adding solar photovoltaics, installing a ground source heat field, renovating the cafeteria and updating the animal habitat.

Also included in the retrofit was installation of an updated building automation system to control and integrate many disparate systems including lighting, security and access control, HVAC and energy metering.

The renovation resulted in 80% energy savings over the MNECB in 2012, an annual energy use intensity of 31.8 kBtu/ft²·year and a 2012 Platinum LEED for Existing Buildings: Operations and Maintenance certification.

**Building Features**

**Thermal Mass**

The building was designed as a thermal mass building, with approximately 5,200 cubic yards of concrete on the interior side of the insulation acting as thermal radiators for the interior spaces in both heating and cooling seasons. This mass acts as a thermal battery, allowing the building to “coast” through temporary spikes or dips in outdoor temperatures.

**Building at a Glance**

**Name**
Earth Rangers Centre

**Location**
Woodbridge, Ontario, Canada, 12 miles northwest of Toronto

**Owner**
Earth Rangers Foundation

**Use**
50% Offices, 50% Animal Ambassador habitat

**Employees/Occupants**
40 employees, 20 tenants, 50 Animal Ambassadors

**Occupancy**
75%

**Gross Square Footage**
63,302 ft²

**Conditioned Space**
60,000 ft²

**Naturally Ventilated/Unheated Aviary**
3,302 ft²

**Distinctions/Awards**
- LEED-NC Gold, 2006
- LEED-EB Platinum, 2012
- Major Renovation: 2010
  - Renovation Scope: Ground source heat field installation plus mechanical systems changes; building automation upgrade, solar PV installation, cafeteria renovation, animal habitat update
- Total Renovation Cost: $4.5 million
- Cost Per Square Foot: $71.09

**EDUCATION**

**BY ANDY SCHONBERGER, P.ENG.**

Above Solar powered faucets powered by ceiling lights, pint-per-flush urinals, low-flow aerators, foaming soaps and other details add up to a functional washroom that minimizes water and chemical use.

Opposite The Earth Rangers Centre reflects the organization’s core values of sustainability.
Reset valves. This is particularly important in cooling mode where the automation system keeps the slab above dew point to prevent condensation formation.

At the Centre, nine 66 ft long and 3 ft diameter concrete tubes are buried 10 ft below the surface. This makes it the largest installation of earth tubes in North America. The earth tubes are the most effective energy-saving feature of the Earth Rangers Centre and supply 100% outdoor air to the building space.

At the ERC, concrete tubes run underground and moderate the temperature of incoming air before the air enters the building. Earth tubes can raise or lower temperatures of incoming air up to 15°F and are well suited to climates that have extremely cold and warm seasons. Large differences between the ambient (external) temperatures and the required indoor temperatures create the best opportunity for earth tubes to passively cool or warm the air according to occupant need.

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Earth tubes supply 100% outside air to the building. This 2003 construction photo shows the prefabricated sections of tube being installed beneath the western foundation.

From www.ercshowcase.com

Landscaping is all drought hardy, native species irrigated only for new plantings with recovered rain and processed wastewater.

Earth tubes supply 100% outside air to the building. This 2003 construction photo shows the prefabricated sections of tube being installed beneath the western foundation.

From www.ercshowcase.com
The earth tube array, in combination with heat recovery ventilation, dramatically reduces energy consumption for fresh air tempering.

The Earth Rangers Centre showcases many sustainable technologies and strategies, including 86 kW of on-site photovoltaic generation.

Above the second floor offices and integrated into the roof structure are clerestory skylights, which face north and admit diffuse light into the spaces. Only on late afternoons in the winter, or on heavily overcast days will the T5, T8s and LEDs be in operation. The lighting control retrofit will optimize control of the lighting system to take advantage of these features. The system is currently being commissioned.

The windows are dual pane, low-emissivity argon-filled windows with insulated edge spacers and thermal breaks. Interestingly, an infrared scan performed as part of the LEED for Existing Buildings certification period showed deterioration in insulating value, most likely as a result of lost argon. Non-destructive testing to determine if repairs are feasible is under investigation. Preliminary investigation has revealed that the energy savings that would result from repairing the existing glazing do not justify repair costs or replacement.

Earth Tubes

Nine 66 ft long prefabricated sewer pipes are buried 10 ft below the surface, beneath the frost line, where ground temperatures remain fairly stable year-round. Fresh air is sucked through these earth tubes, causing the ground’s thermal mass to temper the fresh air.

The system works ideally in heating and cooling seasons (not shoulder seasons), and is coupled with demand controlled ventilation. The temperature of the air that passes through the earth tubes increases by up to 15°F during the winter, without any additional electric or thermal energy required for this air tempering. The energy management information system shows daily averages of outdoor ambient temperatures, after-earth tube temperatures, and post heat recovery temperatures. The tubes are angled away from the building, so that any condensation that forms in humid conditions drains away from the building. Investigation revealed that airflow is not balanced in the tubes, with air preferentially passing through three of the nine tubes. The tubes’ effectiveness could be increased through the addition of dampers. This is being investigated as to cost effectiveness.

A research project with Natural Resources Canada is underway, with

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**DATA CENTERS**

With the help of its industry partners, Earth Rangers redesigned its data center to be significantly (90%) more efficient than industry standard through adopting the most advanced technologies available. The outcome was a “green” data center only 125 ft² in size, with improvement in scalability and performance. These advancements have made it equivalent in ability to data centers many times its size.

It is expected that heat energy generated by the data center’s energy efficient cooling equipment will eventually be recovered and directed to help heat the building and/or domestic hot water. The Earth Rangers Centre implemented a series of improvements, including HVAC, intrusion detection and access control, metering and monitoring (lighting update is being commissioned) that would result from repairing the existing glazing do not justify repair costs or replacement.

**Earth Rangers Data Center**

The Centre’s 28 kW rooftop photovoltaic array generated enough electricity to run its 125 ft² data center in 2012. The data center accounted for 12% of 2012 energy consumption, not including printers, desktops or other office electronics.

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**KEY SUSTAINABLE FEATURES**

- 86 kW on-site photovoltaic generation from two arrays
- 57.6 kW dual axis tracking array on parking lot
- 28.06 kW fixed array on aviary building
- Radiant heating and cooling, with more than 13 miles of tubing embedded in thermal mass construction radiant concrete slabs
- Energy monitoring and monitoring of more than 80 points of consumption including: 65 electric points of consumption 6 water meters 9 thermal energy meters
- Extensive building automation integration, including HVAC, intrusion detection and access control, metering and monitoring (lighting update is being commissioned)
- Nine 66 ft long earth tubes buried 10 ft below the surface to temper 100% demand controlled ventilation requirements. 100% fresh air supply, no recirculation. CO₂, RH and temperature monitoring
- Ground source heat pump system
- R-40 ceilings, R-40 walls
- On-site wastewater treatment plant, capable of treating 3,000 gallons per day of black/graywater for reuse in irrigation, toilet and urinal flushing
- 10,000 ft² green roof
- Extensive stormwater retention features in landscaping design
- 16 solar thermal panels to preheat domestic hot water
- Extensive daylighting and use of skylights
- 9,455 ft² of permeable pavers
- LED lighting for parking lot
- Low mercury fixtures and ballasts

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9 ther mal energy meters
10,000 ft² green roof
Extensive stormwater retention features in landscaping design
16 solar thermal panels to preheat domestic hot water
Extensive daylighting and use of skylights
9,455 ft² of permeable pavers
LED lighting for parking lot
Low mercury fixtures and ballasts
the goal to produce a design guide for building professionals to design earth tubes using lessons learned at the ERC. The report is due in late 2013.

**Air Quality**

The earth tubes themselves provide tempered fresh air to the air handling unit, which incorporates heat recovery in the form of an enthalpy wheel. A strategy of 100% fresh air was chosen because of the presence of animals in the building, in effect making the building a health care-like facility. Animal areas are separately exhausted from office spaces to control indoor pollutants and maintain the highest air quality levels. Air quality levels are also maintained through careful selection of interior design elements. Zero VOC paints are used throughout the facility, and carpet tiles that are taped into position (instead of glued) were chosen over traditional area carpets.

**Water Consumption**

Water consumption also is watched closely via six water meters. With no access to city water or a sewer, all potable water comes from a well, and all wastewater is treated on site.

**ELECTRICITY CONSUMPTION, GENERATION, 2012**

<table>
<thead>
<tr>
<th>Electricity Consumption (Includes Aviary Generation) kWh</th>
<th>Aviary PV Generation kWh</th>
<th>Parking Lot PV Generation kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2012: 63,698</td>
<td>1,149</td>
<td>2,793</td>
</tr>
<tr>
<td>Feb 2012: 59,229</td>
<td>1,636</td>
<td>3,367</td>
</tr>
<tr>
<td>Mar 2012: 48,650</td>
<td>3,127</td>
<td>6,865</td>
</tr>
<tr>
<td>Apr 2012: 44,685</td>
<td>3,647</td>
<td>8,568</td>
</tr>
<tr>
<td>May 2012: 33,825</td>
<td>4,316</td>
<td>10,836</td>
</tr>
<tr>
<td>Jun 2012: 28,662</td>
<td>3,992</td>
<td>9,831</td>
</tr>
<tr>
<td>Jul 2012: 30,046</td>
<td>4,207</td>
<td>9,852</td>
</tr>
<tr>
<td>Aug 2012: 35,941</td>
<td>4,080</td>
<td>9,893</td>
</tr>
<tr>
<td>Sep 2012: 32,472</td>
<td>3,255</td>
<td>7,918</td>
</tr>
<tr>
<td>Oct 2012: 44,124</td>
<td>1,788</td>
<td>4,256</td>
</tr>
<tr>
<td>Nov 2012: 52,174</td>
<td>1,438</td>
<td>3,574</td>
</tr>
<tr>
<td>Dec 2012: 56,448</td>
<td>700</td>
<td>1,386</td>
</tr>
<tr>
<td>Total 2012: 525,954</td>
<td>33,316</td>
<td>80,539</td>
</tr>
</tbody>
</table>

A flat plate membrane bioreactor processes every drop of wastewater from the building. Bacteria present in the bioreactor digest sewage, allowing two separate banks of cartridges to filter out this “activated sludge.” Effluent then proceeds through ultraviolet treatment, and is stored in an 80,000 gallon reservoir beneath the parking lot. This tank also captures rainwater from flat roof surfaces and feeds nonpotable systems as well as fire suppression, should the need arise.

Using the effluent from the treatment plant for toilet flushing and irrigation of the green roof reduced 2012 demand on the local water table by 73%. This avoided potable water use of 452,000 gallons for the period. Consumption levels are minimized through the use of low-flow aerators and toilets, as well as pint-per-flush urinals.
Improving Performance

Energy Metering System

To continue reaching annual energy reduction targets and identify innovative operational strategies, the facilities team realized in 2009 that it needed an extensive energy metering system.

The system monitors more than 80 points of electric and thermal energy, water and gas consumption in the building. It includes multi-circuit electricity meters, third-party Rtu meters, and off-the-shelf water meters. It records average readings over 15-minute windows, and has been recording this data in an SQL database since commissioning in mid-2009.

Running in the data center, the system includes a Web browser and virtualized server, which allow users to access everything from current, voltage, power factor and power quality, to consumption and demand. The system has helped the ERC document energy savings of 15.2% in 2012 over 2010 (savings of 101,418 kWh), and was used to verify the success of various energy initiatives.

Infrastructure Upgrades

More recently, the Canadian Government’s Economic Action Plan supported $2.5 of the total $4.5 million project cost for infrastructure upgrades, including modification of Animal Ambassador habitats, cafeteria expansion, washroom upgrades, wastewater treatment plant enhancements, and a 100-space parking lot with renewable energy systems. The parking lot includes six, dual-axis sun-tracking PV arrays, providing 80,539 kWh (in 2012) of onsite generation, and a geothermal field consisting of 44 wells, each 400 ft deep.

HVAC

This system replaced the previous arrangement of a natural gas-fired condensing boiler and cooling tower with chiller for building heating and cooling needs. The ground-source heat pump arrangement was selected because of the ability to significantly reduce energy consumption and resultant carbon footprint, and the ease of integration with the radiant heating and cooling system. The relatively long simple payback of 18 years was deemed acceptable because these two conditions were met.

The energy metering information and access to the automation system's programming allows ERC operations staff to push the limits on cooling effectiveness by operating the geothermal system in free-cooling mode for the majority of the summer. Ground temperatures are sufficiently cool to allow direct heat exchange with the building’s glycol supply, without using the heat pump for the majority of cooling season. Latent and sensible loads are met using this free-cooling mode for 90% of the season by tracking the dew point of supply air.

The HVAC upgrade initially called for retrofitting the existing ventilation system with 20 variable air volume (VAV) boxes. This was deemed too expensive, and a compromise was reached: six constant air volume (CAV) boxes were installed in existing duct branches. These boxes provide minimum ventilation based on occupancy, and can “purge” a space with fresh air when CO₂ levels rise beyond setpoint.

This demand controlled ventilation is fed from the air-handling unit, which maintains a constant static pressure in the supply ducts. The energy management information allows operations staff to quickly verify that the system is operating as designed and maintaining comfort levels.

Lighting System

The lighting control system, originally a stand-alone LON-based control system, is currently being integrated into the building automation system. It is being monitored by the energy management system, and consumption reduction efforts have largely been restricted to fixture changes, like LED retrofits of track lights and recessed fixtures.

The new control system replaces the LON-based component of the low-voltage relay panels with BACnet compatible controls, allowing direct interface and control of these relays by the base building automation system.

As part of this retrofit, networked occupancy and light level sensors will be added as inputs into the system, replacing local hardwired occupancy sensors that have proven problematic (see Lessons Learned section). This new integration will allow the building lighting to be controlled in a more granular way, as current relay zone groupings are not optimal, along with their schedules.

In addition, the integration of the access control system will be able to inform the lighting control system whether or not the building is in occupied mode, fine-tuning schedules for additional energy savings. As of the date of publication, commissioning efforts are in progress.

Conclusion

The ERC’s energy tracking and saving efforts have paid off. An ENERGY STAR rating of 95 was attained during the LEED EB certification process, and the building’s 2012 energy consumption was 31.8 kBtu/ft². A total of 20 of 92 attained FSC Certified fixtures like those in the print shop enable the production team to prepare high quality programming materials.

WASTEWATER TREATMENT

The integrated water cycle of the building features an on-site wastewater treatment plant and rainwater recovery.
A 3,300 ft² aviary was added to the facility in 2009 to provide an outdoor home to the seven birds of prey that are part of the outreach program. The aviary is naturally ventilated, with overhangs providing shade and shelter to the raptors, and includes a 28 kW rooftop photovoltaic array.

The electricity generated by the aviary PV array and the dual-axis sun-tracking parking lot PV array represented 20% of the energy consumed in the building in 2012. Electricity generated by the aviary PV array is used by the building, while the electricity generated by the parking lot PV array is exported to the grid. The 2012 solar savings fraction for the parking lot PV array was 14% (excluding the aviary). The energy management information system is being used to track this figure on a month to month basis.

The facility participates in Ontario’s Feed-in-Tariff program, which is part of Ontario’s Green Energy and Economy Act and provides an Ontario Power Authority subsidy to participants for generating renewable energy. The subsidies received by the ERC from the aviary and parking lot PV electricity generation offset the majority of the facility’s electricity cost.

Animal ambassadors like Koho the bald eagle go to schools, community shows, and events to connect kids with biodiversity and habitat protection issues.
HIGH PERFORMING BUILDINGS

NATURAL GAS USE, 2012

<table>
<thead>
<tr>
<th>Natural Gas (ft³)</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2012</td>
<td>50,990</td>
</tr>
<tr>
<td>Feb 2012</td>
<td>18,690</td>
</tr>
<tr>
<td>Mar 2012</td>
<td>12,357</td>
</tr>
<tr>
<td>Apr 2012</td>
<td>193</td>
</tr>
<tr>
<td>May 2012</td>
<td>0</td>
</tr>
<tr>
<td>Jun 2012</td>
<td>0</td>
</tr>
<tr>
<td>Jul 2012</td>
<td>0</td>
</tr>
<tr>
<td>Aug 2012</td>
<td>0</td>
</tr>
<tr>
<td>Sep 2012</td>
<td>61</td>
</tr>
<tr>
<td>Oct 2012</td>
<td>306</td>
</tr>
<tr>
<td>Nov 2012</td>
<td>6,663</td>
</tr>
<tr>
<td>Dec 2012</td>
<td>21,105</td>
</tr>
<tr>
<td></td>
<td><strong>110,415</strong></td>
</tr>
</tbody>
</table>

NET ENERGY USE, 2012

<table>
<thead>
<tr>
<th>Energy</th>
<th>kBTU/kW²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Electricity Consumed</td>
<td>28</td>
</tr>
<tr>
<td>Gas Consumed</td>
<td>1.9</td>
</tr>
<tr>
<td>Renewable Electricity (Aviary PV) Consumed</td>
<td>1.9</td>
</tr>
<tr>
<td>Site Energy Consumed</td>
<td>31.8</td>
</tr>
<tr>
<td>Aviary PV Generated</td>
<td>1.9</td>
</tr>
<tr>
<td>Parking Lot PV Generated</td>
<td>4.6</td>
</tr>
<tr>
<td>Net (Consumed–Generated)</td>
<td><strong>25.3</strong></td>
</tr>
</tbody>
</table>

LESSONS LEARNED

Green roof irrigation. The green roof was added at a late stage in construction, and no irrigation system was installed. Dry conditions in the spring of 2010 caused stunted growth on the largest section of green roof (approximately 5,000 ft²). An irrigation system that uses non-potable water along with timers and soil moisture sensors was installed in the summer of 2011.

Reduce landfill waste by educating staff. A garbage audit that was conducted as part of the LEED EB certification revealed contamination of the waste streams and a general lack of knowledge among tenants as to what is actually recyclable and organic. Following the audit, a 90% diversion from landfill rate was set as the target. Staff education efforts and new signage improved the diversion rate to 77%. Diversion from landfill is accomplished through composting of organics and recycling of materials that are accepted by local recycling facilities. Staff education is ongoing, and staff education is included during the Human Resources training process for new employees.

Achieving staff buy-in for LEED EB policies and tracking is an ongoing process. To be fair, the building’s performance has come from significant capital investment, sometimes from donors, and sometimes from corporate partners. Some adopted technologies have very clear, measurable inputs and reliable outputs. After the change an infrared scan of the rooftop could potentially hit the PV solar trackers if parked in the wrong spot. Height restrictor bars were installed to control the type and height of vehicles entering the lot.

Fever ventilation zones leads to increased energy use. To ensure cost savings during upgrades, 26 proposed VAV ventilation zones were aggregated into 6 demand-controlled zones. Entire zones now must be over-ventilated when conference rooms are heavily occupied. This design causes supply and exhaust fans to work harder than needed, and requires greater energy use to temper fresh air.

Lighting control updates need as much attention as mechanical systems. Local occupancy sensors installed into light fixtures were not initially programmed to and after the change an infrared scan of the rooftop could potentially hit the PV solar trackers if parked in the wrong spot. Height restrictor bars were installed to control the type and height of vehicles entering the lot.

To be fair, the building’s performance has come from significant capital investment, sometimes from donors, and sometimes from corporate partners. Some adopted technologies have very clear, measurable inputs and reliable outputs. After the change an infrared scan of the rooftop could potentially hit the PV solar trackers if parked in the wrong spot. Height restrictor bars were installed to control the type and height of vehicles entering the lot.

Waterless urinals have drawbacks. Waterless urinals were an original design feature of the building. They were removed in favor of pint-per-flush urinals because of odor, hygiene, and maintenance costs.

The Centre aims to inspire each one of them to build and operate their own high performance building, doing their part to help “Bring Back the Wild.”

ABOUT THE AUTHOR

Andy Schonberger, P.Eng., LEED AP, is the director of the Earth Rangers’ Centre for Sustainable Technology.