The Waterloo Regional Police Service’s (WRPS) Investigative Services Building demonstrates how innovative sustainable building design can significantly reduce energy use and costs while incorporating the security and design requirements of a crime lab.

The two-story, 4148 m² (44,648 ft²) facility houses forensic science laboratories, garages, offices, meeting and interview rooms and computer rooms. The facility is designed to upgrade the Police Investigative Services’ capabilities to respond to violent crime, homicide, technical crime, fraud, and traffic offenses. To satisfy security concerns, all contractors, consultants, and delivery personnel underwent security screening and wore identification while on site during construction.

Waterloo Region is located in southern Ontario, with a rapidly growing population of about 600,000 concentrated in the “technology triangle” cities of Cambridge, Kitchener, and Waterloo. Climate is typical of southern Ontario: cold winters with −23°C/−2°F design temperature and warm humid summers with 23°C/73°F WB/DB design temperature. The design team sought to minimize the building’s ecological footprint, conserve energy, water and material resources, and provide a healthy place to work.

Energy savings resulted from the following design features and energy management measures.

- **Tight, well-insulated building envelope** with R-17 walls, R-30 roof and R-10 slab-on-grade main floor. Exterior walls consist primarily of 203 mm (8 in.) steel stud framing and R-20 batt insulation and 50 mm (2 in.) spray foam insulation on the exterior, clad with prefinished metal panels. Rigid foundation insulation extends to 1200 mm (4 ft) below grade.

- **Rectangular floor plan** oriented east-west with almost all windows on the north and south.

- **Triple-glazed, double low-e argon windows** with thermally broken panels are located along the bottom of most windows.

- **Efficient ventilation of labs, garages and offices using heat recovery, displacement ventilation and demand control.**

- **High-efficiency condensing boilers** for hot water floor warming and radiation.

- **Energy-efficient lighting and lighting controls.**

- **Commissioning by a third-party consultant.**

- **A long-term building performance monitoring program.**

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**Opposite** The Waterloo Regional Police Investigative Services Building houses police investigation labs, offices and garages. Although it uses simple materials, layout and architectural design, an innovative mechanical/electrical system helped reduce the two-story building’s metered energy use to 52% less than a conventional building of this type.

**Right** A highly efficient series of recessed fixtures for general interior illumination provide a lighting power density between 9–10 W/m² (0.8–0.9 W/ft²) while maintaining a light level of more than 50 footcandles (54 ftlx) on the work surface. A second-floor clerestory window provides natural light.

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**EVIDENT EFFICIENCY**

BY RICHARD LAY, P.ENG., MEMBER ASHRAE; TIM DIETRICH, P.ENG., AND VICTOR HALDER

As any viewer of television crime lab dramas knows, evidence materials must be collected and analyzed under precise laboratory conditions. Forensic investigation laboratories require many energy-consuming designs and systems to meet biosafety regulations and prevent cross contamination.

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**CASE STUDY**

**WATERLOO REGIONAL POLICE INVESTIGATIVE SERVICES BUILDING**

**By Richard Lay, P.Eng., Member ASHRAE; Tim Dietrich, P.Eng., and Victor Halder**

Evident Efficiency

As any viewer of television crime lab dramas knows, evidence materials must be collected and analyzed under precise laboratory conditions. Forensic investigation laboratories require many energy-consuming designs and systems to meet biosafety regulations and prevent cross contamination.
The first year of energy monitoring shows that the WRPS Investigative Services Building used 189 kWh/m² (60 kBtu/ft²) of natural gas and electricity at a cost of $55,700. This is an 11% improvement over the energy model prediction, although the building was 85% occupied for the first year and energy use is expected to go up 9% once the building is fully occupied at 156 full-time equivalent (FTE) occupants.

The building uses 52% less energy than a reference building designed to the Canadian Model National Energy Code and received an ENERGY STAR score of 89. This performance led to the building’s inclusion on the Green Buildings that Work website (www.greenbuildingsatwork.ca), which lists the best performing buildings in Canada by type, based on actual energy use.

**Biolab Ventilation**

Specialized rooms are dedicated to DNA analysis, fingerprint dusting, photography and digital imaging, computer forensics, vehicle forensics, and chemical analysis. Evidence storage, gowning, airlock vestibules, and three additional suites of biolabs are designed to Canadian and World Health Organization biosafety standards to protect evidence from contamination and to protect the health of workers and neighbors.

The biolab suites maintained a negative pressure compared to the rest of the building, and within each suite, the lab itself is maintained positive, with pressure monitors at each doorway. Maintaining

**ENERGY AT A GLANCE**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Energy Use Intensity (Site)</td>
<td>60 kBtu/ft²</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>20.8 kBtu/ft²</td>
</tr>
<tr>
<td>Electricity</td>
<td>39.2 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Source Energy</td>
<td>152.7 kBtu/ft²</td>
</tr>
<tr>
<td>Annual Energy Cost Index (ECI)</td>
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<td>Savings vs. Canadian Model National Energy Code Reference Building</td>
<td>52%</td>
</tr>
<tr>
<td>ENERGY STAR Rating</td>
<td>89</td>
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<tr>
<td>Heating Degree Days</td>
<td>4,279</td>
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<tr>
<td>Cooling Degree Days</td>
<td>109</td>
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</table>

**WATER AT A GLANCE**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Potable Water Use</td>
<td>46,212 gallons</td>
</tr>
</tbody>
</table>

In addition to the HEPA filtration for the laboratories, good indoor air quality is maintained by recessed building entryway grates to capture contaminants, ultraviolet air-sterilizers and steam humidifiers in all air handlers, and partitions, self-closing doors, and dedicated exhaust ducts in all rooms where hazardous chemicals are used. Humidification is provided to ensure acceptable indoor relative humidity levels in winter, while ultraviolet air-sterilizers are included to kill germs.
Handling system with features:
- Dedicated 705 L/s (1,500 cfm) air-nation concerns.
- All ducts are sealed to Sheet Metal and Air Conditioning Contractors’ Association (SMACNA) Class A and leak tested to 2% of the design flow at 490 Pa (2 in. w.g.) for the entire system, including branches and isolation dampers—ambitious airtightness standard, which challenged the measurement limits of the test equipment; and
- All building assemblies enclosing the lab suites are air sealed.

These issues were addressed through a dedicated 705 L/s (1,500 cfm) air-handling system with these features:
- Oversized cabinet to accommodate low face velocity, low pressure drop coils; cabinet factory leak-tested;
- Premium duty, variable speed fans, selected for maximum efficiency, heat pipe heat recovery with zero cross contamination;
- Glycol preheat coil to prevent frost on heat pipes and maintain heat recovery performance all winter;
- Bypass sections around coils and heat pipes to reduce fan power during low loads;
- HEPA filtration on supply and exhaust air;
- Redundant fans to permit uninterrupted lab ventilation during service to AHU;
- All ducts are sealed to Sheet Metal and Air Conditioning Contractors’ Association (SMACNA) Class A and leak tested to 2% of the design flow at 490 Pa (2 in. w.g.) for the entire system, including branches and isolation dampers—an ambitious airtightness standard, which challenged the measurement limits of the test equipment; and
- All building assemblies enclosing the lab suites are air sealed.

Chemistry lab fume hoods are variable flow using sash position sensors and modulating dampers at the individual hoods and dampers at the inlet of the common exhaust fan outdoor air bypass duct, which reduces fume hood exhaust flow when the sashes close and maintains the exhaust fan volume and stack discharge velocity.

HVAC Beyond Lab Areas
The rest of the building beyond the bioblock suites is heated, ventilated, and cooled with a dual duct system supplied by two separate air handlers. One is a 2200 L/s (4,700 cfm) dedicated 100% outdoor air system (DOAS) heat recovery unit. The other is a 7800 L/s (17,000 cfm) recirculating air-conditioning unit with 100% outside air economizer cooling capability.

The heat recovery unit is a reversing flow type, operating at 85% efficiency with no defrost requirement. A reversing damper alternately directs supply and exhaust air through two high mass heat exchange cores every two minutes. The ventilation air handler is ducted to displacement ventilation (DV) terminals low on the wall in each space. Airflow is controlled by occupancy sensors integrated into the lighting control and by two-position dampers so that ventilation is controlled based on actual occupancy. Occupancy sensors give a more accurate signal than CO2 sensors do for actual room occupancy, and they are cheaper, more reliable and easier to maintain. Only meeting rooms are monitored for CO2.

Air-conditioning air is delivered to variable air volume (VAV) terminals in the parallel duct system, so ventilation is controlled independently from temperature. Heating is by hot water reheat coils or heated floors, fed from two modulating, condensing natural gas boilers and variable speed pumps. The HVAC system normally functions with high ventilation efficiency using the dedicated 100% outdoor air AHU and displacement terminals, but it also has full 100% outdoor air cooling capability because of the higher flow rate air-conditioning AHU ducted in parallel to each room. Free cooling capability is an enhancement to a typical DOAS/DV system.
Operable clerestory skylight windows provide natural relief venting during free cooling as well as providing natural light to the corridor. Using off-the-shelf awning windows and power actuators offer acceptable ventilation control and capacity and provide a weatherproof barrier. The same skylight structure serves as the return plenum in winter, harvesting the solar gain from the skylights and distributing the warm air to the building. In the summer, a return air damper is closed, and the air in this hot space is not circulated. Meeting rooms, which have periodically high occupancy, would normally lie the critical zones determining the outdoor air level required by the whole air-handling system. In this building, meeting rooms have a third airflow path—a transfer fan, which injects air from adjacent corridor ceilings, controlled by a CO2 sensor or manual switch. This strategy of secondary recirculation of unused air meets the provisions of ASHRAE Standard 62.1-2004 and is an effective way to maintain good air quality in an energy-efficient manner.

The six-bay garage used for forensic examination of crime scene vehicles is continuously ventilated with two 230 L/s (600 cfm) capacity heat recovery ventilators, supplemented by local exhaust and additional makeup air. The garage is conditioned in winter by hot water heated floors and supplementary fan-coils, and in summer by small split DX air conditioners in critical investigation bays. Pumping energy for heating water is minimized by:

- Selecting pumps for best efficiency;
- Minimizing the need for and use of circuit balancing valves; and
- Permitting flow rates to drop to the minimum required by the building loads, with no three-way bypass flows.

Indoor Air Quality
In addition to the HEPA filtration for the laboratories and MERV 11 filtration elsewhere, good indoor air quality is maintained by ultraviolet air sterilizers in all air handlers and the regular LEED requirements of:

- Recessed floor grates in entrances to capture dirt from foot traffic;
- Partitions, self-closing doors, and dedicated exhaust from all rooms with hazardous chemicals;
- Protecting ductwork and air handlers from dirt during construction; and
- Specifying only low- or no-VOC products for duct sealants, duct liner adhesive, fire stop caulking, and wall and floor finishes and adhesives.

Nonpolluting finishes and furnishings selected to protect air quality include:

- Paints, coatings, sealants and adhesives that meet high standards for low off-gassing of volatile organic compounds (VOCs);
- Carpeting with The Carpet and Rug Institute (CRI) Green Label certification; and
- Composite wood products free of added urea-formaldehyde.

ENERGY END USE

Eleven electricity submeters and gas meters monitor various loads and archive data in the building automation system.

Natural Gas
Space Heating 85%
Domestic Water Heating 15%

Electricity
Plug Loads Including Office and Laboratory Equipment 53%
Lighting 15%
Cooling 16%
Other HVAC Equipment (Fans, Pumps, Small Split AC) and Elevators 14%

High precision variable air volume terminals control supply and exhaust airflow in each lab. Differential pressure is monitored, controlled and locally displayed to inform the operators of actual pressure conditions in the labs.

BUILDING ENVELOPE

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Type</td>
<td>Built-up roofing</td>
</tr>
<tr>
<td>Overall R-value</td>
<td>R-35</td>
</tr>
<tr>
<td>Walls Type</td>
<td>R-8, steel stud, R-20 batt insulation, 2 in. spray polyurethane foam on exterior, metal cladding panels</td>
</tr>
<tr>
<td>Overall R-value</td>
<td>R-18</td>
</tr>
<tr>
<td>Glazing Percentage</td>
<td>13%</td>
</tr>
<tr>
<td>Basement Wall Insulation R-value</td>
<td>R-6</td>
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<tr>
<td>Windows</td>
<td>0.267</td>
</tr>
<tr>
<td>Solar Heat Gain Coefficient (SHGC)</td>
<td>0.21</td>
</tr>
<tr>
<td>Visual Transmittance</td>
<td>0.31</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude 43.41, Orientation East-west</td>
</tr>
</tbody>
</table>

Location
Latitude 43.41, Orientation: East-west

Daylight harvesting provides natural light to perimeter office areas, while lighting controls adjust artificial lighting levels as needed, helping to reduce the lighting load. In addition to the measures to reduce fan energy, the lab fume hoods are designed for variable flow, using sash position sensors and modulating dampers at the fan inlet and hoods. This design reduces fume hood exhaust flow when the sash is closed while maintaining the exhaust fan volume and discharge velocity.

Below, left: A rooftop air-conditioning unit feeds direct expansion cooling coils in AHU-4 for the general building. AHU-4 also has 100% outdoor air capability for free cooling and a dual duct system consisting of a recirculating air-conditioning system and dedicated outdoor air system ventilation ducts.

Above: Occupancy sensors throughout the facility keep lights off in areas not in use. These sensors provide a quick payback on this type of facility that has a 24-hour operation, but is not necessarily at full capacity all of the time. Occupancy sensors rather than CO2 sensors also control ventilation.

Below, right: Another, separate, air-handling unit provides 100% outdoor air to the evidence labs. This lab HVAC system includes variable air volume terminals, heat recovery, HEPA filtration of supply and exhaust and a standby backup exhaust fan.
Rainwater Use
To treat first-flush rainwater, a standard precatch basin provides primary settling and overflow control and uses standard septic tank effluent filters as sediment prefilters in the outlet to the 5000 L (1,321 gallon) precatch concrete rain cistern. Effluent filters are easily serviced, and have high flow rate capability.

LESSONS LEARNED
• Teach the building owner/operator how the metering system works and how to read the data after the monitoring contract ends. For this building, the monitoring consultant conducted a half-day training session with the owner and operator and provided documentation and tools to continue the measurement and verification program beyond the first year of operation.

Potential energy savings were also delayed. If the submeter data are archived to the BAS, then the owner can see real-time data and act on any operating problem immediately. Long-term monitoring ensures good performance. Utility bills provide an overall picture of energy use in a building, but do not provide enough details to dig down and see where the issues actually exist. Submeters provide a breakdown of energy use by system, location and time at as frequent intervals as necessary. The information is provided almost instantaneously in most cases, whereas utility bill information might take up to six months to get to the people managing the building.

Monitoring uncovered several problems:
• Staff noticed condensation and frost on some windows; the monitoring system indicated that some rooms were getting too cool overnight and that the temperature setback sequence was to blame.
• The humidifier setpoint was too high.
• Some air-handling units were not operating as intended.
• A variable speed pump on a glycol heating coil was acting strangely; the pump was incorrectly programmed as on/off.

Rainwater is used for toilet and urinal flushing and supplied 44% of the total water use of 312 m³ (82,309 gallons) for the first year. Only 175 m³ (46,212 gallons) of water was purchased from the municipal utility, 68% less than predicted by LEED Canada. This represented about 21 gallons/day (2.1 gallons/day) for the building's 100 occupants. (The building was not fully occupied the first year.)

Although the plumbing fixtures are good quality, low-consumption (0.6 L [1/6 gallon] dual flush toilets; 0.5 L [0.13 gallon] flush urinals; 1.9 L/min [0.5 gallon/min] lavatory faucets), no exceptional measures were taken to conserve water. All air conditioners are air-cooled, so no makeup water is required for AC equipment. Some exterior hose bibs provide rainwater for occasional tree watering.
but otherwise the landscape design of native plants and noninvasive adaptive plants requires no irrigation.

Rainwater was also initially used for the steam humidifiers in the air handlers because rainwater is free of minerals and does not contribute to scale in the humidifier. However, when the cistern ran low the first winter and was backed up by the hard water from the municipal water utility, the humidifiers experienced a lot of scaling and were switched over to the building’s softened water supply.

**Conclusion**

Measurement and verification monitoring during the first year of operation demonstrated that the facility is using less energy than predicted by the Natural Resources Canada EE4/DOE 2 energy model—a good result particularly in the first year of operation when most buildings require extensive commissioning to meet their energy saving potential.

The WRP Investigative Services Building achieved its green objectives, received LEED Gold certification, was constructed within budget, is using less energy and water than predicted and after two years’ occupancy, the owner is satisfied with the building.

**Utility Costs, 2009**

<table>
<thead>
<tr>
<th>Cost (CAD)</th>
<th>Cost per m² · yr</th>
<th>MNECB Reference</th>
<th>Reduction from Reference Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>$46,900</td>
<td>$11.31</td>
<td>$78,400</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$8,800</td>
<td>$2.12</td>
<td>$24,900</td>
</tr>
<tr>
<td>Total Energy</td>
<td>$55,700</td>
<td>$13.43</td>
<td>$103,300</td>
</tr>
<tr>
<td>Water (Indoor, Outdoor)</td>
<td>$300</td>
<td>$0.07</td>
<td>$6,800</td>
</tr>
</tbody>
</table>

Note: Intensity is based on gross floor area.

**Water Use, 2009**

The building realized significant water savings of 96% (indoor and outdoor use) versus the baseline building’s water use. These water savings can be attributed to the innovative water conservation features at the building, including rainwater storage and low-flow fixtures. During this period, the cistern contributed 44% to the total water used at the building. Water used from the rainwater cistern was 137 m³ (36,177 gallons), compared to city water at 175 m³ (46,212 gallons). Outdoor water use was significantly reduced by using water conservation measures including the use of native or noninvasive adaptive plants that are drought resistant. This eliminated the need for irrigation.

**Energy Use, 2009**

The building realized significant energy savings of 40% (electricity) and 60% (natural gas) versus the baseline building’s energy use. These energy savings can be attributed to the innovative energy conservation features at the building, including the use of high-efficiency equipment and systems. During this period, the building used 46% less energy than predicted by the Natural Resources Canada EE4/DOE 2 energy model—a good result particularly in the first year of operation when most buildings require extensive commissioning to meet their energy saving potential.

**About the Authors**

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