TowerWise
Case Study:
Appleby Woods

1. Executive Summary

Appleby Woods is a superb example of how much energy can be saved when it comes to new building construction by simply planning ahead. Developer Del Ridge Homes built on previous experience with systems like insulated concrete forms (ICF) to integrate a number of new energy saving features in this six storey 101-unit building.

Project Component	Cost
Ground-source heat exchange system	$1,800,000
Suite-based DHW tanks	$1,700,000
Solar PV Array	$450,000
Solar-powered LED parking lot lighting	$178,000
Total Project Cost	$22,000,000
Project Performance	
Annual Energy use per square foot	10ekWh
Reduced Annual CO_2 emissions compared to typical low-rise residential building	330 Tonnes
Project payback on the incremental cost of green features	0 years

Despite a number of advanced features, ranging from a geo-exchange linked HVAC system to rooftop solar panels, the mid-rise condominium in Burlington, Ontario was actually less costly to construct than more conventional surrounding condos, meaning buyers paid roughly 25% less per square foot of space compared to other new buildings in the same area. They also enjoy condo fees that are about 60% less than those for neighbouring buildings thanks to this building's high level of energy efficiency.

For construction costs, a lot of the savings came from using pre-fabricated materials and the ICF system. For building operations, savings are largely the result of a well insulated building envelope (R45 walls and 10" of rigid foam insulation on roof) with high thermal mass, a low window-to-wall ratio (less than 15%, compared to a more typical 40-70%), and geo-exchange (aka, geothermal) heating and cooling for the entire building.

With a solid base to work from, Del Ridge then added features like sensor-controlled parking garage lighting, CO sensor controlled parking garage fans, solar powered LED outdoor lights, and highly insulated water heater tanks in each unit to further drive down energy use. This combination of measures made it more realistic to meet some of the building's energy needs through renewable energy systems, including a solar photovoltaic system and the geothermal-supplied HVAC system.

Appleby Woods demonstrates that we can build multi-residential buildings that consume significantly less energy and produce significantly fewer climate damaging emissions at no extra cost. In fact, Del Ridge is already taking the lessons from this project and applying them to new projects that will take energy savings even deeper.

2. Project Description and Rationale

When Dave De Sylva, his son Anthony and George Le Donne began the Appleby Woods project, their aim was to set a new benchmark for Del Ridge Homes in sustainable building design.

Del Ridge quickly realized that the foundation for any truly sustainable building had to be excellent energy efficiency and conservation built into the structure itself. They achieved this with a building system that provided high levels of insulation and high thermal mass that could store heat in winter and retain cool in summer longer than conventional structures.

A building with significantly lower energy demands meant that renewable energy systems could then be used to meet some or all of the building's energy needs, making it practical to install both solar photovoltaic and geothermal heating and cooling systems.

Building Envelope

From previous Del Ridge projects, including Prentice Place and Parkview Place in Markham, the builder knew that use of insulated concrete forms (ICFs) could reduce energy use and, in some cases, capital costs.   For example, based on temperature monitoring in five other ICF-lined parking garages, Del Ridge found that the average minimum temperature in the garages was 16°C without any additional heating and with the garage doors opening and closing constantly. This told them they no longer needed to include parking garage heaters in new developments when using ICF components.

ICF wall

ICF walls are constructed from rigid foam blocks that snap together like Lego bricks to create concrete forms with permanent insulation. The increased thermal resistance and thermal mass provided by this system makes it much easier to maintain a relatively constant temperature in the building. For Appleby, Del Ridge used an ICF wall for the building envelope consisting of five inches of XPS and eight inches of concrete for an R45 insulation value. The ICF walls were paired with a steel superstructure and pre-cast hollow core concrete slabs in the full building structure. The roof insulation was also increased from the typical four inches of rigid foam to 10 inches. Finally, to minimize overall heating and cooling losses, the window-to-wall ratio was reduced to less than 15%, compared with a typical multi-unit residential building ratio of 40-70% (Finch et al. 2010).

Renewable Energy Systems

After reducing energy demand through a better building envelope, renewable energy technologies including solar photovoltaic (PV) panels and a ground-source heat exchange system were used to meet some of the building's energy needs as well as to further reduce utility costs.

Ground-Source Heat Exchange System: To meet the in-suite heating and cooling demand, pumps are used to transfer heat between the ground and the building though 54 boreholes underneath the outdoor parking lot. Groups of four underground loops each meet at headers that feed into a pump. There are two pumps per floor operating alternately so there is always capacity in the event that one pump fails. The pumps feed into a hydronic loop with a branch going to a fan coil unit in each suite. Each of these fan coil units contains a heat pump and fan that delivers or removes heat from the suite as needed.

The condominium corporation owns the ground source heat exchange field in the parking lot and the infrastructure in the building up to the suite connection, while the residents own the equipment in their suite (heat pump and fan, etc.).

Solar Photovoltaic Array

Solar Photovoltaic System: In an effort to get as close to zero net energy use as possible, the developers opted for a grid-tied PV system to offset some of the electricity demand from the building. They installed a 30kW roof-mounted solar array at a 30° angle. At the time of construction this system was the largest privately owned residential solar array in Ontario. After being grandfathered into Ontario's Feed-in-Tariff program in 2010, the Appleby condo corporation was able to offset the capital cost of the system with revenue from electricity production. The Appleby Woods development also includes solar-powered LED lights in the parking lot on the south side of the building, which did not require any connection to an external source of electricity, thereby reducing labour costs associated with installation.

HVAC and DHW Systems

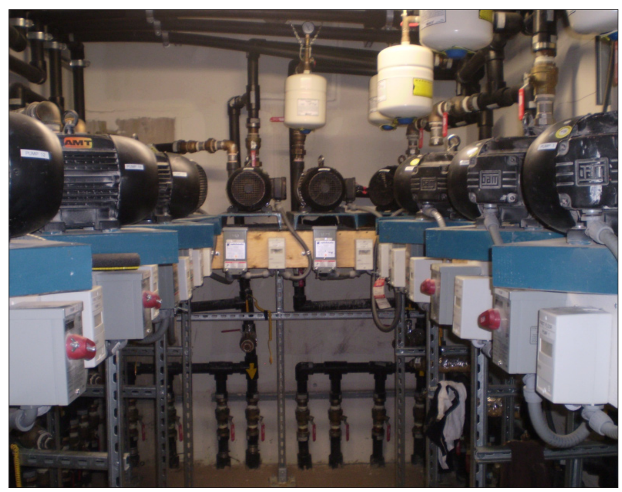
Conditioned ventilation air is provided by a conventional rooftop air handling unit with a natural gas heater. However, from previous experience, Del Ridge found that condominium owners prefer to control the environment in their suite rather than relying on centralized settings, which led them to equip the building with suite-level systems and controls. Heating and cooling is provided by the water-to-air heat pump described above while domestic hot water is provided by a 40-gallon tank in each suite. The tanks have additional thermal wrapping over what was supplied by the manufacturer to reduce energy use. Given the experience Del Ridge has with previous ICF buildings, they were also able to eliminate the heating system in the garage.

Other building systems

There are a number of other building features included at Appleby Woods that Del Ridge considers standard for a green development, including dual flush toilets, EnergySTAR-rated appliances, low emissivity argon-filled double glazed window units, non-incandescent lighting, and CO monitoring in the parking garage to control exhaust fan operation. As well, after determining that individual parking stalls were actually in use for less than 1% of the day, they added off-the-shelf passive infrared motion sensors to the parking stall lighting system. Aisle lighting in the garage is provided by CFLs.

3. Construction Process

Despite the inclusion of a number of unconventional building techniques and technologies, the construction of Appleby Woods proceeded on schedule and on budget.



Pumps for the ground source heat exchange system

However, finding an experienced contractor to complete the ground-source heat exchange work was a challenge because these systems are far less common than conventional heating and cooling equipment. In the end, the system was installed by two different contractors: one was responsible for drilling the boreholes and installation of the exterior piping, and the second connected the exterior system to the building distribution system. The two contractors worked together with the mechanical contractor, who determined the heating and cooling demand for the building and sized the system at appropriately 135ft/ton. The system consists of 54 boreholes, each 525 feet deep, and 12 seven-horsepower pumps, circulating a continuous ethyl-glycol-water supply throughout the building.

The ground-source heat exchange system was designed to meet 100% of the heating demand for the building. However, because the heat loss performance improvements of the ICF envelope were not factored in, building code requirements could not be met by the geothermal system alone. This meant that electric heaters had to be added to each unit. Ironically, as the heaters did indeed prove to be unnecessary, they were disconnected prior to the building even being occupied.

The roof-mounted solar photovoltaic system has been operational since construction but it took nine months for payments to start flowing from the provincial Feed-in Tariff program. In fact, Appleby's system actually pre-dated the program and therefore had to be grandfathered into the FIT program at a rate of $0.70 per kilowatt hour of energy produced.

Use of pre-fabricated components such as ICF blocks and hollow core slabs cut construction time for the structural components by about half (the building was erected at a rate of about 2.5 weeks per 32,000 square feet of floor area, including all of the unit partitions). Another time and money saver was the installation of 18 solar-powered LED lights in the parking area in front of the building. Because these were standalone units with no power system connections, installation required no additional permits, electricians, trenching or Electrical Safety Authority inspections.

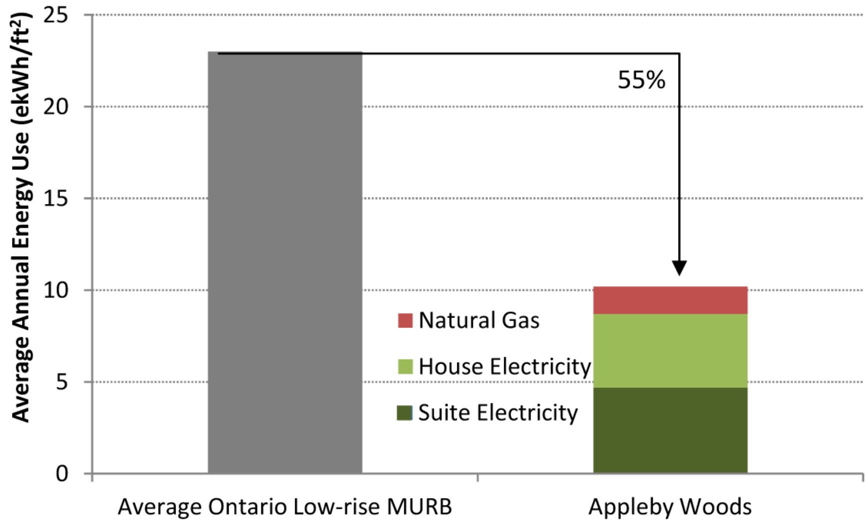
4. Project Performance

Based on a study of the High-rise Building Statistically Representative (HiSTAR) Database developed by Natural Resources Canada and the Canada Mortgage and Housing Corporation, the average energy use for a low-rise (4-6 storey) multi-unit residential building constructed between 1986 and today is 23kWh/ft^2 (Liu 2007.) Based on usage from February 2011 to June 2011, the estimated annual energy consumption at Appleby Woods is 10ekWh/ft^2, less than half the average usage reported by NRCAN. The HiSTAR building group selected for comparison includes buildings that are up to 25 years old, some of which may be performing less efficiently than when they were first constructed. However, even when compared with the best energy performers in the low-rise building group (1961-1985: 20ekWh/ft^2), the energy intensity of Appleby Woods is still remarkably lower (Liu 2007). This energy use reduction results in an annual savings of 330 equivalent tonnes of CO_2, compared with similar buildings (Natural Resources Canada 2010).

HVAC system

The geothermal system has proven capable of fully meeting the heating and cooling needs of the building. Even on the rare occasion when the loop flow is interrupted and an entire floor loses access to the ground-source heat, it takes a day or so for the occupants to notice that the heat has not switched on. This demonstrates that the improved thermal resistance prevents heat loss while the increased thermal mass slowly releases heat stored by the walls into the space. Similarly, the lack of a heating system in the

Figure 1: Average Annual Energy Use



parking garage has not created any issues. The minimum temperature recorded to date in the garage was 13.5°C, which is slightly lower than the average of Del Ridge's other test buildings because the footprint of the parking garage extends beyond the perimeter of the above-grade structure.

However, there does seem to be higher-than-necessary energy use by the primary pumps driving the geothermal loop through the building. Currently, the loops run constantly at a uniform flow rate and the fans in each unit will turn on and off as required by the in-suite thermostat. In an attempt to reduce the pump energy use by up to 60%, Appleby is now in the process of installing variable frequency drives on each of the pumps. This will allow flow to be adjusted according to the actual demand to heat or cool suites.

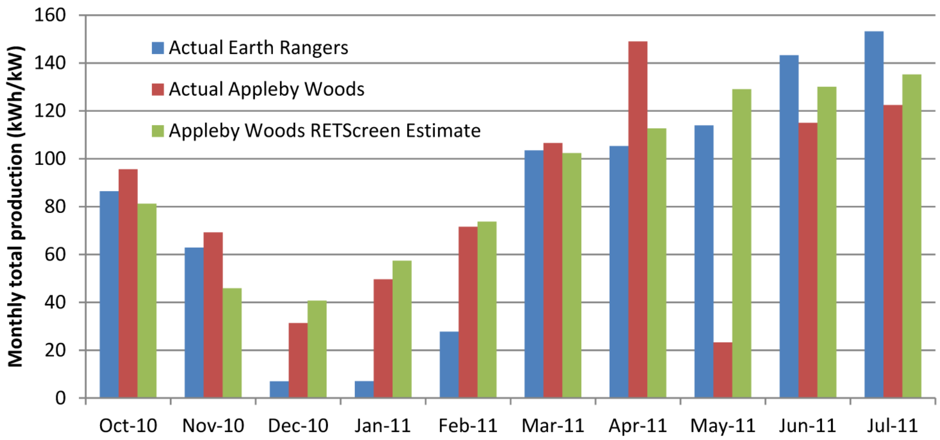
The geothermal system also lacks a notification system for when the flow through a loop has stopped due to a pump malfunction or other reasons. Faster notification will mean issues can be resolved before residents even notice any problems.

Solar Photovoltaic Array

The solar photovoltaic array has supplied about 1.4% of the overall electricity used by the building since the system became a part of the Feed-In Tariff program in September 2010. From September 2010 to April 2011, the array performed quite well as compared with another nearby installation as well as to production estimates from RETScreen, a software program used to evaluate renewable energy technologies. However, in May 2011 there was a dramatic drop in electricity production, as shown in Figure 2, which is as yet unexplained.

Possible contributors to this reduction may be inverter issues or perhaps a misallocation of production data given the recorded over-production in April 2011, although the building manager has not been able to find evidence of this. Performance since has not quite been restored to pre-May 2011 levels.

Figure 2: PV Production Comparison



This issue illustrates the importance of carefully monitoring building systems. If the May malfunction had persisted and continued undetected, Appleby could have lost thousands of dollars in revenue.

Parking Lot lights

Instead of typical 150W Metal Halide (MH) lamps, 60W Light Emitting Diode (LED) lamps were used to achieve the same lighting levels for the Appleby Woods parking lot on the south side of the building. These lamps are powered by pole-top PV panels connected to a battery pack with a nine day storage capacity, meaning the lights will remain operational even over extended cloudy periods.

The LED lights also have a service life that is several times longer than that of high pressure sodium (HPS) or metal halide (MH) lights traditionally used in outdoor parking lots (> 50,000 hours versus approximately 30,000 hours for HPS lights or 20,000 for MH - U.S. DOE 2008), which will reduce the annual maintenance costs associated with re-lamping (OKSolar 2011).

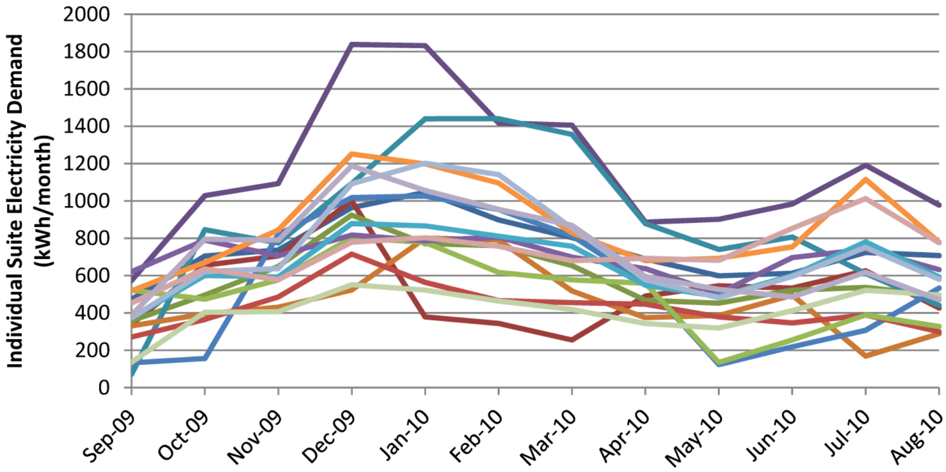
5. Project Costs

The total cost of the Appleby Woods project was about $22 million including: $1.8 million for the ground source heat exchange system; $1.7 million for the suite-based DHW tanks; $450,000 for the solar PV array; and $178,000 for the solar-powered LED parking lot lighting.

Even with the improved building envelope, suite-based equipment and renewable energy systems, the purchase price for the Appleby Woods condominiums was about 25% less than that of other buildings in the area at $220-225/ft^2 compared to $300/ft^2. In addition to a lower purchase price, owners enjoy lower monthly fees: about $0.16/ft^2 compared to about $0.42/ft^2 for other buildings in the area due to a reduction in energy demand as well as supply by renewable sources. Based on an average suite of about 1,200ft^2, that is a savings of about $3,700 per year on condo fees.

Residents are also responsible for their in-suite electricity use associated with plug loads, the DHW tank and the heat pump and fan. The electricity demand difference between suites is quite dramatic, with a 760 kWh consumption difference between the highest and lowest user. This wide difference illustrates the value of suite-based metering both as an incentive to conserve energy and for fairness between residents. In-suite electricity costs, however, only add approximately $60 per month to unit carrying costs, meaning Appleby's fees remain a bargain.

Figure 3: Electricity Use Profile of Ground Floor Suites



The prefabricated structural components like the ICF walls and hollow core slabs have a higher capital cost but are also much quicker to install, which saves on labour costs. Similarly, the solar-powered parking lot lights were also quicker to install. Though the stand-alone LED lights represented a higher capital cost, their full lifecycle cost is actually less, as shown in Table 1.

Table 1: Life cycle cost comparison between parking lot lighting types (Signature Lighting 2011)

	Metal Halide	Solar LED
Capital cost	$4,000	$8,000
Life cycle (years)	20	20
Re-lamping cost	$50	$600
Lamp life cycle (years)	4	10
Ballast replacement cost	$200	Included in re-lamping
Ballast life cycle (years)	8	
Operating Energy (W)	180	60
Annual operating cost (assume 12hrs/day, $0.07/kWh	$788	$263
Total annual life cycle cost	$1,026	$723

The suite-based equipment also added to the capital cost of the project. For example, the heat pump plus connection to the ground loop cost $6,000 per suite, while each suite's share of the cost of the ground source heat exchange system was $7,000, for a total of $13,000 per suite, about twice as a much as a typical through-wall combined heating and cooling unit.

However, the geothermal system is much more efficient than a conventional HVAC system and involves only modest external energy inputs, making it a good bargain over the long run for residents.

The solar photovoltaic array has been operational since construction was complete, but the system only began generating revenue for the condominium corporation when the FIT contract was signed in late 2010. To date, the system has provided about $18,000 in revenue over the first ten months of FIT- eligible operation. Based on this performance, the system will have a simple payback of 21 years.

To offset some of the incremental capital costs of the project, Del Ridge applied for the High Performance New Construction incentive from the Ontario Power Authority. By reducing the building's kW load during peak periods they received $50,000.

6. Lessons Learned

Based on the knowledge gained on previous projects, Del Ridge knew to incorporate ICF walls, eliminate parking garage heating, install motion-sensors for stall lighting in the garage, increase the thermal resistance of the roof and provide thermal wraps around the DHW tanks in their projects. With Appleby, they went a step further by incorporating a ground-source heat exchange system, solar PV panels, and solar powered LED outdoor lighting. All these measures have been quite successful, although issues with both the solar PV and geo-exchange systems demonstrate the value of careful systems monitoring and fine tuning.

That Appleby managed to deliver large energy savings without a large increase in unit cost – in fact, at a lower cost than conventional buildings -- can be put down to careful planning and integrated design. Paying close attention to the quality of the building envelope was, for example, critical to support the addition of advanced options like geo-exchange by making it possible for the ground-based energy system to meet the building's significantly reduced energy needs. Similarly, reducing electricity demand with high efficiency lighting, motion sensors, VFDs and solar powered outdoor lights allowed the PV system to meet more of the building's electricity needs.

Del Ridge is now carrying these lessons over to its latest project, GreenLife Milton. GreenLife will be a six-storey building with about 150 suites and the developer's first attempt at a full Net Zero building (energy produced on site equals energy consumed by the building over the average year). Thanks to the evidence gained from Appleby, Del Ridge has not been required to install electric heaters in GreenLife suites. It has also decided to install a solenoid valve in each unit's fan coil so the geo-exchange ground loop only circulates to a particular suite branch when heating or cooling is required, which will reduce the energy required for pumping. Also, instead of one header for every four bore holes, they will use a single header for the entire building to improve mixing and even out the temperature of the circulation fluid. The DHW tanks are going to be wrapped with even more thermal insulation than at Appleby Woods so will require less energy to maintain the standby water at required temperatures. This may also reduce the required suite cooling in summer.

To determine the true lifecycle cost impact of the ground-source heat exchange system versus a suite-based combined heating and cooling system, GreenLife will compare both systems side by side. One suite will contain an electric through-wall heating and cooling system, while an adjacent suite will be connected to the ground-source heat exchange system and contain a heat pump instead of a heating and cooling coil.

There will also be a 260kW photovoltaic array on the roof of GreenLife. Based on an average output of 975kWh/kW from the 30kW Appleby Woods array the output for GreenLife will be about 250MWh per year, generating approximately $175,000 in FIT revenue, which could further reduce condominium fees. It should also be possible to improve solar system performance by 10-20% compared to Appleby.

7. Conclusions

By applying lessons from other developments and experimenting with newer techniques and technologies, Del Ridge has been able to reduce the energy use and operating costs of the Appleby Woods condominium by half, compared to other low-rise residential buildings. By considering the building as a system, they first reduced energy demand and then offset some of that demand with on-site renewable energy supplies. Compared to an equal size average Ontario multi-unit residential building, Appleby Woods emits approximately 57% less CO_2 on an annual basis.

Incorporation of suite-level control allows residents to control their own interior environment while being responsible for their own energy use.

The success of Appleby Woods proves that low-energy buildings can be designed and constructed in a cost-effective way and has prompted Del Ridge to to take the next logical step and aim for net-zero energy at their latest development.

8. Acknowledgements

Special thanks to Dave De Sylva, Anthony De Sylva and George Le Donne for their assistance with the development of this case study.

9. References

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Glossary

Coefficient of Performance (COP) – A measure of the efficiency of a heat pump. The COP is a ratio of the energy output to the energy input. (Source: Natural Resources Canada)

Equivalent Carbon Dioxide (CO2e) – A measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one metric ton of methane are equivalent to emissions of 21 metric tons of carbon dioxide. (Source: Organisation for Economic Co-operation and Development)

Ground-Source Heat Exchange – Using a liquid-driven loop, the ground is used as a heat source or sink during the winter and summer, respectively. In winter, a heat pump is used to extract heat from the liquid coming out of the ground and deliver it to an incoming air stream. In summer, the heat pump is reversed thereby extracting heat from the air and delivering it to the liquid loop for deposition in the ground. (Source: Natural Resources Canada)

Heat Pump – A heat pump transfers heat from one place to another by using a refrigerant loop that includes a compressor, condensing loop, expansion valve and evaporator loop. One common example of a heat pump is a refrigerator. (Source: Natural Resources Canada)

Heating Degree Day (HDD) – Represents the amount of heating energy required during the heating season. It is measured by the difference between the base temperature of 18°C and the mean temperature for a particular day. (Source: Natural Resources Canada)

Insulated Concrete Forms (ICF) – Lightweight blocks made from two layers of expanded polystyrene or extruded polystyrene which are separated by a steel or plastic web. The blocks are assembled and used as concrete forms that are left in place. (Source: InsulatedConcreteForms.ca)

Low-emissivity (Low-E) Windows – Low-E coatings are microscopically thin, virtually invisible, metal or metallic oxide layers deposited on a window surface primarily to reduce the thermal conductance by suppressing radiative heat flow. (Source: Efficient Windows Collaborative)

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TAF's TowerWise program works with high-rise owners and managers to reduce energy use and emissions from apartment towers and condominiums. TowerWise provides unbiased advice and assistance to help high-rise owners make their buildings more comfortable and less polluting. To get involved with the TowerWise program, contact Lyle Jones at ljones@tafund.org, 416-393-6370