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Major Energy Retrofit Guidelines

for Commercial and Institutional Buildings

NON-FOOD RETAIL

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Natural Resources Canada's Office of Energy Efficiency
Leading Canadians to Energy Efficiency at Home, at Work and on the Road

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The guidelines are an adaptation of the United States Environmental Protection Agency's *ENERGY STAR Building Upgrade Manual*. Natural Resources Canada gratefully acknowledges all those who have contributed to their production.

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ENERGY RETROFIT OPPORTUNITIES IN NON-FOOD RETAIL

PART 1

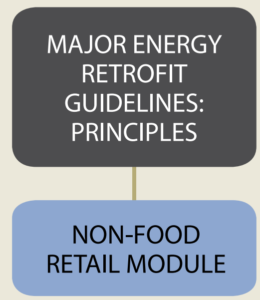
The Non-Food Retail Module complements the proven energy retrofit approach outlined in the Principles Module. This module, which should be considered as a companion document to the Principles Module, discusses strategies, priorities and opportunities specific to non-food retail buildings.

The Non-Food Retail Module is divided into three parts:

1. **Energy Retrofit Opportunities in Non-Food Retail:** Provides an overview of Canadian non-food retail buildings. Subsections present background information on each retrofit stage and key retrofit measures, with a focus on small and medium-sized non-food retail buildings.

2. **Case Study:** The case study showcases a successful major energy retrofit project.

3. **My Facility:** This take-away section provides an Energy Efficiency Opportunity Questionnaire to assist you in identifying opportunities in your facility.



Non-food retail stores focus on a wide range of merchandise options and include department stores, discount stores, drugstores, home centres/hardware stores, and other apparel/hardline specialty stores (e.g. books, clothing, office products, toys, home goods, and electronics).

This module addresses the most common type of non-food retail building. This type of building is accessed directly from the outdoors and is served by an independent heating, cooling and ventilating system, most commonly, a rooftop air handling unit (RTU). Non-food retail buildings that are part of a shopping mall or enclosed plaza have different environmental conditions due to characteristics such as common interior spaces (e.g. in malls) and, in some cases, central HVAC systems.

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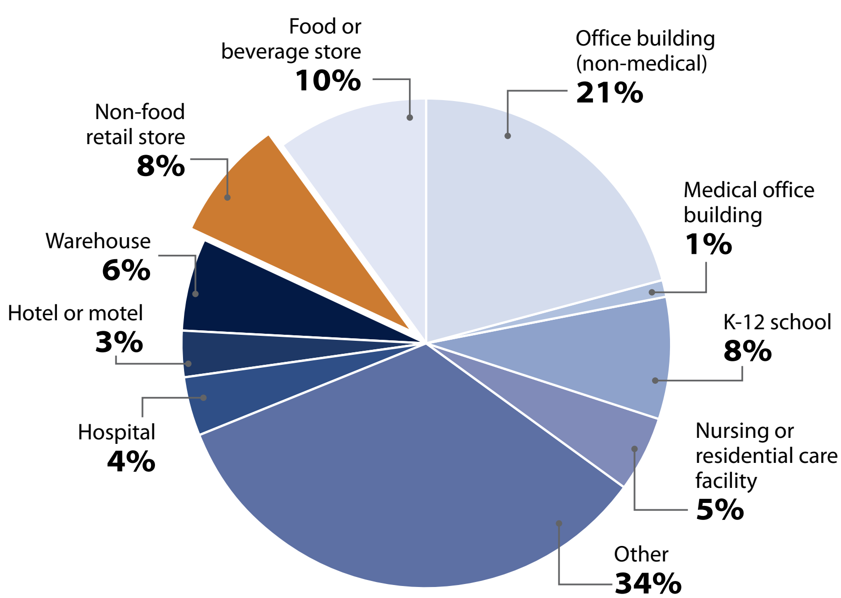
Non-food retail overview

Call to action

Commercial and institutional buildings account for approximately one-eighth of the energy used in Canada.[1] Over the next 20 years, the stock of commercial buildings is projected to grow by over 60%, and it is expected that 40% of existing buildings will be retrofitted.[2]

Figure 1. Commercial/institutional energy use by subsector



Data Source: NRCan 2012. Survey of Commercial and Institutional Energy Use – Buildings 2009: Detailed Statistical Report.

Figure 1 shows that, within the commercial and institutional buildings sector, non-food retail stores are the third largest energy-using subsector, accounting for around 8% of energy use. As the name implies, this subsector includes stores that sell primarily non-food consumer goods and includes stand-alone facilities (e.g. box stores), open air or strip malls (a collection of attached stores with common areas that are not enclosed), and shopping mall anchors. As the building stock ages, a tremendous opportunity exists to undertake major retrofits that will improve the energy performance of non-food retail stores across the country.

By implementing a proven major energy retrofit strategy, beginning with benchmarking using ENERGY STAR® Portfolio Manager, you can positively impact your building's bottom line.

[1] Natural Resources Canada. 2013. *Energy Use Data Handbook, 1990-2010*.

[2] Commission for Environmental Cooperation. 2008. Green Building Energy Scenarios for 2030.

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Opportunities and challenges

The financial benefits of more energy-efficient buildings are widely known. In the retail sector, energy is one of the most controllable expenses and one of the few expenses that can be decreased without negatively affecting your operations. Many organizations have invested in energy efficiency to improve the building environment for employees and customers, to improve building performance and financial returns, to cut energy costs, and to demonstrate their commitment to sustainability.

There are numerous reasons why you may be initiating a major retrofit in your facility. Major capital equipment or building infrastructure, such as your rooftop units or your roof, may be nearing the end of its useful life. You may be experiencing equipment control problems (e.g. multiple rooftop units being controlled individually), or you may have malfunctioning equipment as a result of deferred maintenance. Major internal space changes may also trigger a retrofit. Regardless of the reasons, there are a number of common opportunities and challenges that apply to non-food retail stores when undertaking major retrofits.

Opportunities

Energy savings are one of the principal benefits of a major retrofit project. Energy savings lead to reduced energy costs, which directly improves your bottom line. In other words, the profitability of your store will improve as you reduce your operating costs through lowered energy consumption. A related benefit for building owners is the increase in asset value. Energy savings can lead to higher net operating income and a higher building valuation. Lower energy consumption also limits your vulnerability to energy price fluctuations and reduces your greenhouse gas emissions.

Beyond energy savings, a notable benefit of major energy retrofits is often an improved indoor environment. Major retrofits in non-food retail stores often enhance aesthetics and create a more pleasant shopping environment. For example, upgrades to lighting and HVAC systems can lead to a better customer experience and increased sales.

Many retailers also want to demonstrate their corporate social responsibility to potential customers. Today, 60% of global consumers want to buy from environmentally responsible companies.[3] Non-food retail stores can enhance their public image and attract and retain more customers by undertaking major energy retrofits. For example, green building certification provides recognition of an environmentally responsible, high-performance building that is valued in the market by customers, investors and tenants.

Identify major retrofit triggers unique to your facility in order to optimize the timing of your projects and incorporate energy efficiency into your capital plan. For more information, see Section 2 of the Principles Module.

You should also plan to meet, or ideally exceed, the minimum performance requirements outlined in the most recent version of the National Energy Code of Canada for Buildings (NECB).

[3] Green Brands Survey, Global Insights. 2011. cohnwolfe.com/en/ideas-insights/white-papers/green-brands-survey-2011.

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Case in point:
Toss Salon
Ottawa, Ontario

To upgrade its lighting, Toss Salon invested just $328 in addition to $1,136 in incentives it received from Hydro Ottawa's Small Business Lighting Program. The retrofit reduced annual electricity consumption by 5,818 kWh—enough to power an average home for seven months.

Source: Hydro Ottawa

Finally, benchmarking your building's energy performance presents an opportunity in itself. Benchmarking at the start of a retrofit process, and again during improvement phases, allows you to measure relative improvements, justify expenditures, and establish a new baseline to help monitor future performance.

Challenges

The competition for financing poses a real challenge in the retail building sector, particularly for retail chains. Because equipment and building infrastructure related decisions for retail chains are made at the corporate headquarters level, financing for building upgrades must compete with funding allocated for new construction. For example, **big box retailers** often look for payback periods of two years or less on projects in existing buildings, largely because the funds needed for these projects compete with the capital required for opening new stores.

Not surprisingly, many **smaller non-food retail store** owners do not have comprehensive asset management plans. Since building equipment and infrastructure are typically replaced or renewed only upon failure, it is important for building owners to determine which components need to be replaced and when the replacements should be scheduled.

For retail spaces located in **strip malls**, major retrofits are likely to need special consideration. The ability to upgrade some or all of the building equipment in a particular space will depend on lease agreements, whether spaces are served by their own HVAC or other systems, and the building owner's willingness to participate in the process.

Unlike other non-food retail buildings, large **enclosed malls** typically include centralized HVAC systems, sophisticated building automation systems, significant common areas, and ancillary services such as food courts and parking garages. Although these large facilities are not the focus of this module, some of the unique energy management challenges related to these buildings are discussed briefly in the relevant sections.

For all non-owner occupied buildings, common leasing arrangements can also pose a barrier to implementing energy retrofits because of the disconnect between who pays for the retrofits and who receives the benefits. Such an arrangement is commonly referred to as a "split incentive" between the owner and the tenant. As a result, when it comes to financing energy retrofits, building owners and tenants often perceive the negotiation process as a zero-sum game of winners and losers, where one party pays while the other benefits. A survey of decision makers responsible for energy use in buildings and published by the Institute for Building Efficiency in 2012[4] identified split incentives as one of the barriers to capturing energy savings in buildings.

[4] Institute for Building Efficiency. buildingefficiencyinitiative.org/resources/2012-eei-global-results-presentation.

Green leases (sometimes referred to as aligned leases, high-performance leases, or energy-efficient leases) are one way to remove this barrier. Owners and tenants can agree on lease terms that share the benefits of lower utility bills, giving owners an incentive to invest and tenants an opportunity to achieve savings.

Two organizations have developed guides and templates for green leases:

- The Real Property Association of Canada's (RealPAC) *Green Lease Guide for Commercial Tenants*, available on their website: **realpac.ca/?page=GreenLeaseGuidefo**
- Building Owners and Managers Association's (BOMA) *Commercial Lease: Guide to Sustainable and Energy Efficient Leasing for High-Performance Buildings*, available for sale on their website: **store.boma.org/shopping_product_detail.asp?pid=52168**

Retrofit timing is an especially important issue for retail facilities. In addition to assessing major retrofit triggers such as equipment replacement schedules, retailers must consider seasonal business patterns and their customers' willingness to accept disruption within the building.

Energy use profile

When planning your major retrofit project, consider the energy use profile for a typical Canadian non-food retail store. Although specific energy use profiles will vary depending on the type of store (e.g. drugstore vs. electronics store), the example below can be used to provide a general indication of how you use your energy.

Figure 2. Energy use by energy source

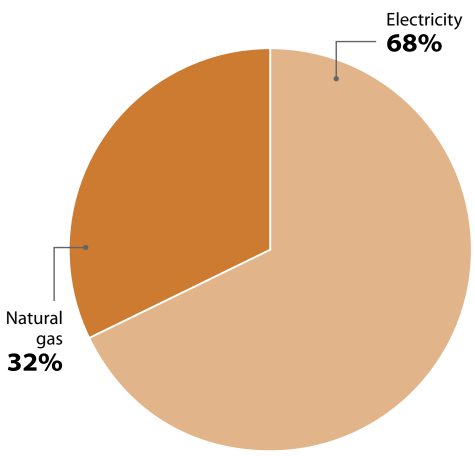
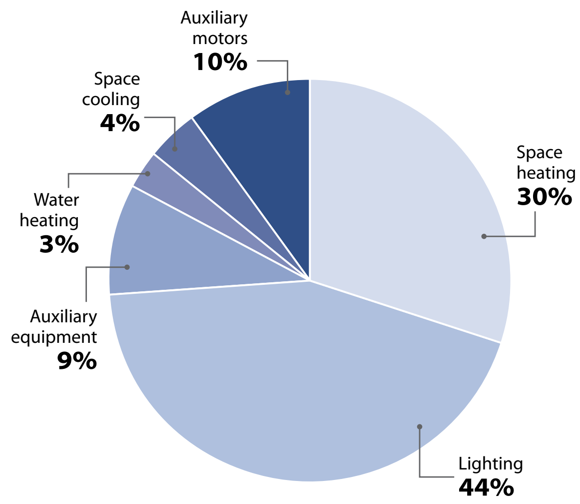


Figure 3. Energy use by end use



End use data for a typical medium non-food retail store in the interior of British Columbia with climate conditions similar to other metropolitan areas across Canada.

Source: 2011 FortisBC Conservation Potential Review, Commercial Sector.

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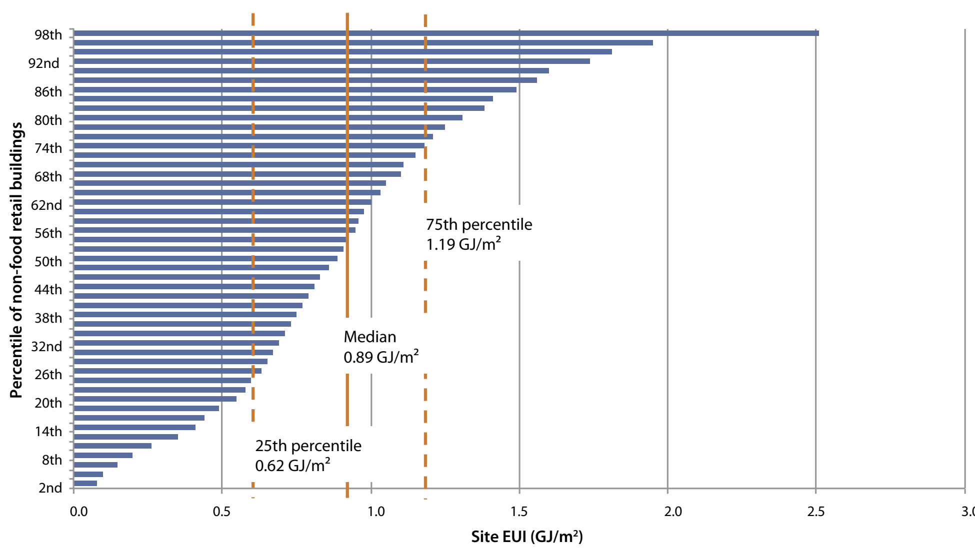
Note: 1 Gigajoule (GJ) is equal to 278 equivalent kilowatt-hours (ekWh), or the energy content of approximately 27 cubic metres (m^3) of natural gas.

Figure 2 shows the breakdown of consumption by energy source. In this example, electricity provides over two thirds of the store's energy requirements. Figure 3 shows the breakdown of consumption by end use. Lighting is the largest end use, followed by space heating and auxiliary motors (e.g. rooftop unit fans) and equipment.

Energy use intensity (EUI) in non-food retail stores can vary widely and is influenced by weather conditions and specific operating characteristics such as weekly hours of operation, number of workers, number of personal computers and cash registers, the nature of the other auxiliary loads (e.g. electronic merchandise, elevator and escalator motors), and the percentage of a facility's space that is heated and cooled.

Figure 4 presents the overall distribution of normalized EUI for a Canada-wide sample of non-food retail stores.

Figure 4. Distribution of site energy use intensity for Canadian non-food retail stores



Source: ENERGY STAR Portfolio Manager, 2016

The solid vertical line shows that the median EUI for non-food retail buildings entered in ENERGY STAR Portfolio Manager is 0.89 GJ/m^2 (22.97 ekWh/sq. ft.). Buildings in the 25th percentile of this data set have EUIs lower than 0.62 GJ/m^2 (16.0 ekWh/sq. ft.) and those above the 75th percentile have EUIs greater than 1.19 GJ/m^2 (30.71 ekWh/sq. ft.). The national median EUI according to the *Survey of Commercial and Institutional Energy Use* 2009 is 0.9 GJ/m^2 (23.2 ekWh/sq. ft.).

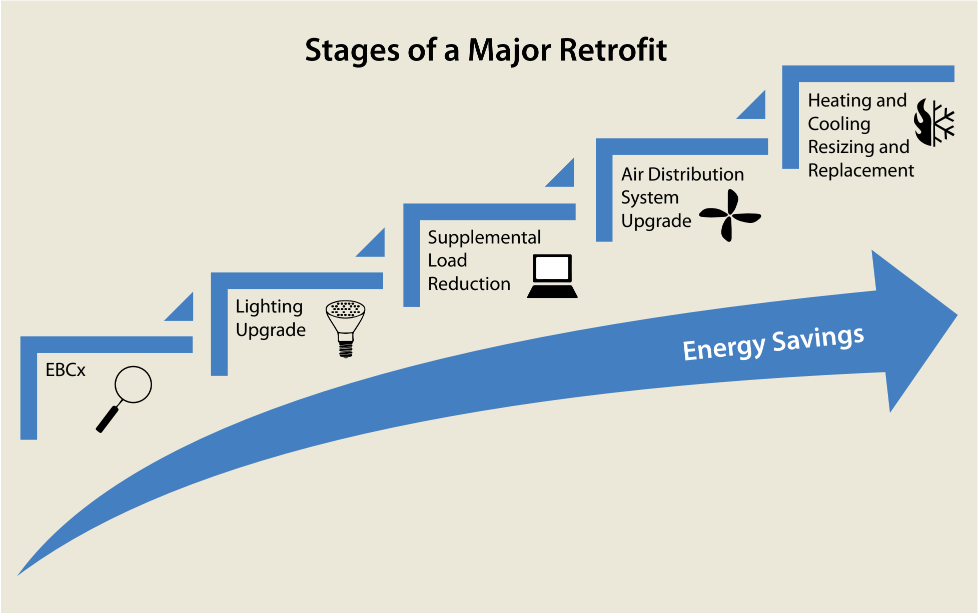
Building owners are encouraged to benchmark and track their energy performance using ENERGY STAR Portfolio Manager, the most comprehensive and only standardized energy benchmarking tool in Canada for non-food retail stores. Benchmarking allows you to compare your current energy use against past performance as well as against that of similar buildings. The results provide an excellent baseline to measure the impact of energy and water efficiency retrofits and are a powerful motivator to take action to improve building energy performance.

It is worth noting that EUI in non-food retail stores can vary widely and therefore it can be misleading to assess a store's performance solely by looking at its average EUI. For example, stores with lighting, appliance or home entertainment sections will likely have higher consumptions if display units are left on all day.

Staging project measures

As discussed in the Principles Module, implementing major retrofits in a staged approach is the most effective way of improving facility energy performance.

Each stage includes changes that will affect the upgrades performed in subsequent stages, thus setting the overall process up for the greatest energy and cost savings possible.



Adapted from the U.S. EPA's Energy Performance Rating System.

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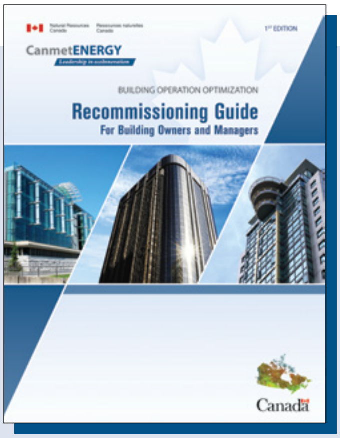

For more information on existing building commissioning, refer to NRCan's *Recommissioning Guide for Building Owners and Managers* to learn how to reduce expenses and increase revenue through improved building operations.

Existing building commissioning

Commissioning is a first-order activity to improve an existing building's energy performance. Field results have shown that existing building commissioning (EBCx) can achieve energy savings ranging from 5 to 20%, with a typical payback period of two years or less.[5]

Savings from commissioning are achieved by improving building operations and restructuring maintenance procedures. Natural Resources Canada's (NRCan) *Recommissioning Guide for Building Owners and Managers*[6] shows you how to reduce operational expenses through improved building operations.

In Section 1 of the Principles Module, we explained how an EBCx program has four phases: assessment, investigation, implementation and hand-off.

During the assessment and investigation phases, EBCx involves a detailed survey of the existing systems, including documenting the configuration and sequence of operations. The result is a collection of operational knowledge as well as a list of measures to correct any deficiencies.

During the implementation phase, any deficiencies are corrected, and the savings opportunities identified during the assessment and investigation phases may be implemented. The overall philosophy of the work done at this stage is to ensure that all systems, equipment and building controls are properly configured and fully operational.

The measures listed below represent some of the typical improvements made under EBCx. It is important that all measures be implemented with suitable commissioning to ensure that system retrofits are optimized.[7]

[5] Thorne, J., and Nadel, S. 2007. *Retrocommissioning: Program Strategies to Capture Energy Savings in Existing Buildings*. Prepared for American Council for an Energy Efficiency Economy.

[6] *Building Operation Optimization: Recommissioning Guide for Building Owners and Managers.* nrcan.gc.ca/energy/efficiency/buildings/research/optimization/recommissioning/3795.

[7] The Canadian Standards Association's Z320-11 standard provides guidelines for the commissioning of buildings and all related systems, and has been developed to deal with buildings and their major systems as a whole, rather than as individual stand-alone components. It can be applied to new construction as well as renovations of existing buildings or facilities. shop.csa.ca/en/canada/building-systems/z320-11-/invt/27032582011.

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EBCx measure list

- ✓ Confirm lighting control schedule
- ✓ Schedule air handling system
- ✓ Employ temperature setback during unoccupied hours
- ✓ Verify free cooling operation (air side)
- ✓ Calibrate building automation system sensors
- ✓ Widen zone temperature deadband
- ✓ Close outside air dampers during morning warm-up in the heating season
- ✓ Perform early morning flush in the cooling season when conditions allow

- **Confirm lighting control schedule:** Confirm that the lighting control schedule matches the actual occupancy, and explore opportunities to reduce hours of operation by reducing or eliminating after-hours activities (e.g. cleaning, stocking) by moving them to existing occupied hours. Controls should typically be configured to turn interior lights off at a set time, but not on; occupants are expected to turn lights on when they arrive in the morning.

- **Schedule air handling system:** Equipment that runs longer than necessary wastes energy. Equipment schedules are often temporarily extended, then forgotten. Check that equipment scheduling in the building controls, mechanical timeclocks or thermostat settings matches occupancy as closely as possible.

- **Employ temperature setback during unoccupied hours:** One of the most cost effective means of reducing energy consumption is by modifying the temperature set point of the building when it is empty, i.e. letting the thermostat go below the occupied period set point during the heating season, and above it during the cooling season. Setback temperatures typically range from 2 to 5 °C; however, the actual appropriate setback levels depend on the recovery time of your facility's HVAC equipment, i.e. the time it takes to bring the space temperature back to a comfortable level before staff arrive. Review the set points for heating and cooling during unoccupied hours to ensure that setback temperatures are in place.

- **Verify free cooling operation (air side):** In free cooling mode, a building's economizer and exhaust air dampers are fully opened to bring in the maximum amount of cooler, drier outdoor air. Strategies to control the free cooling opportunity include fixed enthalpy, differential enthalpy, differential dry-bulb, etc.

  Economizers are a commonly overlooked or forgotten maintenance issue with air handling units (AHUs). A study prepared by the New Buildings Institute in 2004 found that 64% of economizers failed due to broken or seized dampers and actuators, sensor failures, or incorrect control.[8]

The **Retail Council of Canada** launched an Energy Efficiency Services program in 2013. The program offers expertise on facility energy conservation incentive programs, product-based energy efficiency marketing, capacity building, and counsel on energy pricing and regulatory pricing. Technical experts offer members complimentary services such as support in processing incentive applications, energy data analysis and walk-through energy audits.

Information: retailcouncil.org

[8] New Buildings Institute, Review of Recent Commercial Roof Top Unit Field Studies in the Pacific Northwest and California, October 8, 2004. newbuildings.org/sites/default/files/NWPCC_SmallHVAC_Report_R3_.pdf.

When an economizer is not controlled correctly, it can go unnoticed because mechanical cooling will compensate to maintain the discharge air at the desired discharge air set point. This may include periods of time when too much or too little outdoor air is being introduced through the AHU or rooftop unit (RTU). Failure to correct or mitigate this situation will likely lead to increased fan, cooling, and heating energy consumption.

The impact of an improperly working economizer is significant. For example, across Canadian climate zones, a recent study found the average annual energy savings available from free cooling in a 5,000-m^2 building to be approximately 19,000 kWh.[9]

- **Calibrate building automation system sensors:** Building automation systems rely on the information provided to them by various sensors throughout the building. Sensors for temperature, carbon dioxide and enthalpy (total energy content of air) are just a few examples. If the critical sensors in a building are inaccurate (i.e. out of calibration), the building systems will not operate efficiently, costs will increase and comfort issues can result.
- **Widen zone temperature deadband:** Zone temperature deadband is the temperature range in which neither heating nor cooling is provided to the zone. By widening the zone temperature deadband, unnecessary "fighting" between heating and cooling systems is prevented, and energy consumption is minimized. This also mitigates heating and cooling system instability caused by short-term cycling between heating and cooling modes.
- **Close outside air dampers during morning warm-up in the heating season:** While warming the building before the occupants arrive, make sure the outside air dampers are fully closed. This saves energy by heating recirculated air, rather than colder, outside air.
- **Perform early morning flush in the cooling season when conditions allow:** During the cooling season, pre-cool the building with 100% outside air (when outdoor air conditions permit) before starting mechanical cooling. To accomplish this, the controller senses acceptable outdoor air conditions and delivers an override signal to the outdoor air or economizer damper to open fully. During this operational mode, heat recovery must be disabled to take advantage of the free cooling.

[9] Taylor, S. and Cheng, C. "*Why Enthalpy Economizers Don't Work.*" *ASHRAE Journal.* November 2010. nxtbook.com/nxtbooks/ashrae/ashraejournal_201011/index.php?startid=79#/14.

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Lighting upgrades

Lighting consumes over 40% of the energy used in Canadian non-food retail stores and affects other building systems through its electrical requirements and the waste heat it produces. Upgrading lighting systems with efficient light sources, fixtures and controls reduces lighting energy use, improves the visual environment, and can impact the sizing of HVAC and electrical systems.

Lighting upgrades are often attractive investments with relatively low capital costs and short payback periods. Even simple upgrades can reduce lighting energy consumption between 10 and 85% and have the potential to improve employee health and productivity.[10] If one considers that prescribed lighting power densities (LPDs) from older codes are at least double the LPDs prescribed in current codes, an energy saving potential of 50% is possible, even without additional controls.

Direct replacement vs. designed retrofits

Direct replacement retrofits require little analysis and, as the term implies, are a one-for-one replacement of lighting sources and/or control devices. For instance, new 11-W light-emitting diode (LED) lamps can replace 50-W MR16 halogen incandescent lamps.

On the other hand, designed retrofits require analysis and design exercises to ensure that the resulting lighting layout and control strategy meets occupants' needs. Lighting designs need to address important elements such as luminance ratios, glare and colour qualities, in addition to the quantity of light. The National Energy Code of Canada for Buildings (NECB) should also be consulted to ensure that maximum LPDs are not exceeded.

Table 1. Illuminance recommendations for retail facilities

Application and task	Illuminance targets (lux)[11]
General retail	500[12]
Dressing rooms	300
Shipping and staging	300
Stock rooms	300
Circulation	75-200[13]

Source: The Lighting Handbook, 10th Edition, Illuminating Engineering Society of North America (IESNA)

HVAC implications of interior lighting retrofits

Lighting systems convert only a fraction of their electrical input into useful light output; much of the rest is released directly as heat. Any lighting upgrades that reduce input wattage also reduce the amount of heat that must be removed by the air conditioning system.

Although this decreases the need for air conditioning in summer, it also reduces the available heat from lighting during winter months. The precise effect on any given building can be determined by computer simulation. On the whole, installing energy-efficient lighting is a very effective measure to drop peak electrical demand, reduce energy consumption and lower utility costs.

[10] Consortium for Building Energy Innovation. *Best Practices for Lighting Retrofits, Picking the Low Hanging Fruit*. Revised August 29, 2013. research.cbei.psu.edu//research-digest-reports/best-practices-for-lighting-retrofits.

[11] Recommended maintained horizontal illuminance levels measured at 76 cm above floor, where at least half of the observers are 25 to 65 years old.

[12] General retail levels vary depending on the type of merchandise and the degree of display or accent lighting.

[13] Levels vary depending on the type of merchandise.

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Key lighting terms

Colour rendering index (CRI): A 1-to-100 measure of the ability of a light source to reveal the colours of various objects correctly in comparison with an ideal or natural light source. A CRI of 100 is ideal.

Fixture efficiency: The ratio of lumens emitted by a light fixture to the lumens emitted by the lamp(s) installed in that fixture.

Lighting efficacy: A measure of light output per unit power input. Measured in lumens per watt (lm/W).

Lighting power density (LPD): A measure of connected lighting load per unit floor area. Measured in watts per square metre (W/m^2).

Lumen: A unit measuring total light output emitted by a light source (lm).

Luminaire: A complete lighting unit (lamp, fixture, lens, ballast, wiring, etc.).

Lux: A unit of measure of illumination equal to one lumen per square metre (lx). The imperial unit is the foot-candle (fc), equal to one lumen per square foot.

When designing lighting modifications, the following principles apply:

- Design lighting layouts in accordance with the principles of the Illuminating Engineering Society of North America (IESNA) standards.
- Ensure that LPD is equal to or lower than that prescribed by the NECB.
- Use the most efficient light source for the application. For example, high-performance fluorescent systems as the primary light source for most commercial spaces; LEDs in place of incandescent bulbs.
- Use daylight whenever possible, but avoid direct sunlight, as it introduces glare issues. Install controls to reduce the use of electric lights in response to daylight.
- Use automatic controls to turn off or dim lights as appropriate.
- Plan for and carry out the commissioning of all lighting systems to ensure that they are performing as required. Create a schedule to recommission systems periodically.

Lighting measures are discussed in the context of three typical non-food retail environments: retail, warehousing, and exterior/parking lot lighting.

Retail

Lighting in a retail environment is designed to attract customers, provide sufficient lighting for the evaluation of merchandise, and facilitate completion of sales. In addition, lighting can be a key element of a store's atmosphere and helps to communicate the retailer's brand image.

Customer attraction and product attention

Once customers are in the store, lighting is used to direct their movement to product displays. Human beings are phototropic — their movement can be directed by the intentional placement of light, much like a moth's attraction to light. In addition to directing customers to product displays, lighting is also used to direct the flow of customer traffic in a particular pattern.

Atmosphere and brand image

Retailers use lighting not only to sell product, but also as a mechanism to create an atmosphere that reflects their brand image:

- Retailers selling high-quality or exclusive products and specialized services will focus on lighting that reflects their image. Warm light sources with low levels of general (ambient) lighting and high-intensity accent lighting are often used to create a comfortable atmosphere that encourages customers to browse and spend longer periods of time in the store — which usually equates to spending more money.

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- Retailers who promote low prices and a wide range of merchandise will use basic lighting systems with uniform light levels and cool temperatures. This type of lighting approach supports the message that customers are getting the best deals and not paying for the retailer's high overhead costs in the products they purchase.

Reflectance of interior surfaces

Lighting performance is greatly affected by the reflectance of interior surfaces, such as walls, ceilings, flooring, shelving and merchandise. A black or dark-coloured wall or ceiling will not be as reflective as a white wall. For example, a space with two brown walls and two white walls may require six luminaires to provide the light levels required. The same space with four white walls will require only four luminaires. Keep in mind that shiny metal surfaces will reflect light, while dark-coloured merchandise and containers will absorb light.

Lighting and the *National Energy Code of Canada for Buildings*

LPDs have decreased due to advancements in energy-efficient lighting systems. The 1997 Model National Energy Code for Buildings permitted LPDs for retail ranging from 22.6 to 35.5 W/m^2, depending on building size. The NECB 2011 prescribes a maximum average building LPD of 15.1 W/m^2 for retail buildings.

Guide to calculating LPD

1. Identify boundaries in the area of study, and measure and calculate the floor area in square metres.
2. Collect input power or amperage for each lighting fixture type in the area. This should be available on an electrical data label applied to fixtures. Do not use lamp wattages. Where input power is indicated in watts, use this value. Where input current is provided in amperes, multiply the amperage by the voltage (120 V or 347 V) to obtain the wattage.
3. Calculate the sum of the fixture input wattages and divide by the area to determine LPD in watts per square metre.

General lighting is necessary in the selling area to permit easy navigation through the main aisles and check out areas. It is commonly achieved using a fixed lighting system, such as a pattern of fluorescent or high-intensity discharge downlighting from the ceiling.

Display and accent lighting is designed to attract customers and aid in evaluation of merchandise. Accent lighting requires more light than the surrounding area for contrast—at least five times as much—depending on the texture and colour of the merchandise displayed.

Display and accent lighting systems should be flexible, such as a track lighting system, to adjust to changing display needs. Proper design involves paying special attention when adjusting the lighting system to minimize direct and reflected glare into the eyes of customers.

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High-bay lighting technology

High-bay lighting in retail environments has traditionally come in the form of high-intensity discharge (HID) metal halide (MH). However, in recent years, standard HID lighting has been replaced by fluorescent or the new ceramic MH; most recently, high-bay LED fixtures have also entered the market. There are a number of factors involved in the assessment of light fixture selection:

- Light output: Lamp lumen output is rated as initial and mean, where the mean represents the light output at 40% of its rated life. MH fixtures emit only 65 to 80% of their initial lumens by the time they hit mean lamp life and as low as 40% of their initial lumens by the end of lamp life. Fluorescent lamps maintain 90 to 94% of their initial lumens through the end of lamp life (9,000 hours). LEDs, on the other hand, retain over 90% of their output at 60,000 hours.[14]
- Fixture efficiency: This is a function of the fixture's design and its ability to project the available lumen output from the lamps. Most existing HID fixtures have an overall fixture efficiency between 60 and 70%. High-bay fluorescent fixtures have efficiencies greater than 90% due largely to the highly reflective qualities of the fixture reflectors.
- Lamp life: Lamp life depends on the frequency of switching, influenced by the number and duration of on-off cycles. The longer the on-time frequency, the longer the life of the lamp.
- Colour: CRI is a quantitative measure of the ability of a light source to reveal the colours of various objects correctly in comparison with an ideal or natural light source; the higher the number, the better the CRI. Metal halide CRI is 65, while high-output fluorescent CRI ranges from 80 to 85. For LED lighting, CRI is not considered a true indication of how colour is rendered. When colour temperature is important, LED may not be the right choice, despite its other advantages.
- Warm-up period and switching: Fluorescent lamps have a typical warm-up period of less than 1.5 seconds, while MH lamps have a warm-up period approaching three minutes. Similarly, fluorescent lamps will restrike (switching back on after being turned off) in less than 1.5 seconds, while MH lamps take approximately 17 minutes. This is an important factor if daylighting and other lighting control strategies are implemented. For example, on days where daylighting is highly variable, the delayed response of MH fixtures may produce undesirable lighting conditions.

[14] IESNA TM-21-11, diode junction temperature 55 °C.

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Fluorescent T8 or T5 high-output

T8 lamps provide a better quality of light with less glare in areas where the fixture height is lower than 6.1 m (20 ft.). T5 high-output (T5-HO) lamps deliver a brighter light source within a smaller diameter and, if paired with a properly designed reflector, will provide better quality light output and higher fixture efficiency.

As a general rule of thumb, a **T5-HO fixture should be used in applications above 6.1 m (20 ft.) and T8 fixtures below 6.1 m (20 ft.)**. There is a range between 5.5- and 7.6-m heights (18 to 25 ft.) where either T8 or T5-HO fixtures can be used successfully.

LED lighting

When LED fixtures first entered the market, they were expensive and had limitations on colour and brightness. Advances in LED technology and manufacturing, however, have produced lower-cost fixtures with suitable colour ranges and lumen output. Furthermore, LED lamp life is estimated to be 50,000 to 100,000 hours, compared to 24,000 to 36,000 hours for fluorescents and 18,000 hours for high-bay HID fixtures. Lamp replacement costs are an important consideration when assessing the application of LED fixtures as a retrofit option. LED fixtures are now acceptable replacements for incandescent fixtures and lamps, exterior lighting and, in increasingly more cases, fluorescents.

Although LED technology as a replacement for area lighting in retail buildings has the lowest life-cycle cost, it may not have the colour characteristics acceptable for the desired lighting effect. High-bay LED fixtures currently have CRIs in the range of 70. Advancements with LED lighting source quality and fixture manufacturing are rapidly closing the cost and colour rendering gap and may be suitable for retail environments in the near future. **Because this technology is advancing so quickly, LED options should be discussed with your lighting designer.**

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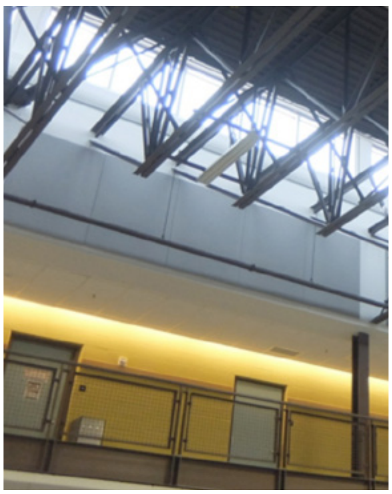
Figure 5. Skylight



Daylight harvesting

Daylight harvesting makes use of natural light as a source of illumination. Buildings that use daylight (and can therefore switch off or dim electric lighting) have the potential to cut energy use, reduce peak demand and create a more desirable indoor environment. However, it takes careful planning to achieve all the potential benefits from a daylighting system, and it can be challenging in existing buildings where windows and other light openings are already fixed.

Successful daylighting offers significant benefits with respect to comfort and occupant satisfaction, energy savings, and increased sales in a retail environment. Poor daylighting designs, however, result in glare and irregular luminance, and ultimately occupant dissatisfaction. When redesigning the lighting system, daylighting design should be the first step in the lighting design process. Electric lighting design should then be focused on complementing daylight during daytime and providing proper illumination on its own during nighttime.

Skylights introduce natural light without taking away valuable wall space desired for merchandising. To understand the impact of daylighting on retail sales, a study was carried out on a retail chain of 108 almost identical stores. Two thirds of the stores had skylights and one third did not. With fluorescent being used as the source of general lighting, the skylights provided two to three times the target illumination levels. The results of the study showed that skylights had a positive and strong correlation to higher sales by 40%.[15]

Energy savings from daylighting

Energy savings are available with well-designed daylighting when coupled with a daylight-responsive lighting control system. When there is adequate ambient lighting provided from daylight alone, this system has the capability to reduce electric lighting power. Other benefits include:

- *Reduced cooling load.* Compared with electric lighting, daylight delivers more of its energy as visible light and less as heat. Therefore, daylight can reduce cooling loads when it replaces electric light. However, the benefit of daylighting is more complex, as thermal losses and conductive gains through glazing are also factors to consider. Shading controls can reduce heat gains, and appropriate window glazing selection is necessary to reduce thermal loss through the glazing. Overall, a well-executed daylighting design will reduce cooling loads.
- *Reduced peak electricity demand.* Daylighting is particularly well suited to retail buildings since they are usually occupied during the day when natural light is available. When daylight availability and summer outdoor temperatures are high, daylighting can substantially reduce peak electric loads due to the reduction in mechanical cooling and electric lighting demands. Even in the winter, savings in electric lighting can reduce peak electrical demand. This will result in monthly savings in demand charges.

[15] Heschong Mahone Group, *Skylighting and Retail Sales, An Investigation into the Relationship Between Daylighting and Human Performance*. August 20, 1999.

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Daylighting controls

Lighting controls have two forms: switching and dimming. Both strategies require sensors to provide feedback to the controls.

- Switching turns lights off when adequate daylight is available. Existing lighting circuits can be re-wired to enable separately circuited ballasts within each fixture or separately circuited light fixtures.
- Dimming provides gradual changes to the light output over the ballast's range, allowing a wide range of light output. Dimming control is typically more acceptable in facilities with standard ceiling heights. It is less useful in high-bay lighting applications, because occupants are less sensitive to changes in lighting levels, making switching the better option.

Case in point:
Costco daylighting strategy

Costco's daylighting strategy reduced lighting consumption in its stores by 50%. The daylighting system consists of diffusing skylights, 2.4 m x 1.2 m each, covering approximately 4% of the roof area, and photosensors that control all the lighting fixtures in the store. A minimum of 550 to 650 lux (51 to 60 fc) is maintained at all times by switching light fixtures on and off in three groups to provide a stepped response to daylight. Operating costs were minimized by integrating the photosensors with the store's energy management system.

Source: Daylighting Initiative, Design Tools and Information from PG&E, Pacific Gas & Electric, 1999

Lighting measure list (retail)
✓ Replace incandescent lamps that are used often with LED lamps
✓ Replace incandescent Exit signs with LED signs
✓ Replace wall switches in enclosed rooms with occupancy/vacancy sensors
✓ Replace high-intensity discharge lighting with high-bay fluorescent
✓ Install daylight sources and lighting control
✓ Circuit lighting for after-hours activities

- **Replace incandescent lamps that are used often with LED lamps:** For example, MR16 incandescent lamps have been the most common source of lighting for accent and display lighting. Savings of almost 80% are available by directly replacing a 50-W MR16 lamp with an 11-W LED with CRI of 92.
- **Replace incandescent Exit signs with LED signs:** Exit signs can be replaced entirely or converted to LED with a retrofit kit. Savings are significant given that Exit signs are on 24 hours, seven days a week.
- **Replace wall switches in enclosed rooms with occupancy/vacancy sensors:** Occupancy and vacancy sensors turn lights off when spaces are empty. Occupancy sensors automatically turn lights on when occupancy is detected; vacancy sensors require manual activation of the wall switch to turn lights on. Vacancy sensors deliver the highest savings since the lights will never automatically turn on. A time-out period of 15 minutes is typical to avoid short cycling and reduced lamp life. The U.S. Environmental Protection Agency (EPA) estimates savings potential under optimal conditions ranging from 25 to 75% of lighting energy depending on space type.[16]

[16] U.S. Environmental Protection Agency. *Putting Energy into Profits: ENERGY STAR® Guide for Small Business*. energystar.gov/ia/business/small_business/sb_guidebook/smallbizguide.pdf.

Lighting upgrade provides added customer bonus

Replacing 116,000 of its incandescent spotlights with LED lamps in 165 stores will save Sears Canada more than $2 million in electricity cost savings over the 10-year lifetime of the lamps.

Before launching the Canada-wide project, Sears tested several LED products and their effects on customer sales. Unexpectedly, there was a notable reduction in merchandise returns due to the improved CRI of the new lighting (i.e. fewer customers were returning items because they were the wrong colour).

"The LEDs have a truer colour in comparison to the older incandescent lamps," said James Gray-Donald, former associate vice president.

Source: saveONenergy program, Ontario's Independent Electricity System Operator

- **Replace high-intensity discharge lighting with high-bay fluorescent:** Replacing quartz MH lighting with T5 high-output lighting offers 23% energy savings.
- **Install daylight sources and lighting control:** A well-designed daylighting strategy with photosensor lighting controls that switch off fixtures when adequate daylight is available can save significant energy as well as maintenance costs.
- **Circuit lighting for after-hours activities:** Restocking and cleaning activities generally do not require the same level of lighting as that designed for the customer. Lighting energy can be reduced by re-wiring existing lighting circuits to enable separately circuited ballasts within each fixture or separately circuited light fixtures.

Warehouse

The lighting in inventory storage and receiving areas serves a different purpose than the lighting applied where customers view and purchase merchandise. Warehouse lighting serves the more technical functions of worker visibility, safety and performance.

The light levels and visibility required in a warehouse will depend upon a number of factors, including the tasks performed, the age of the workers and the type of space (open spaces vs. racks). In high-activity areas, such as loading docks or staging areas, the light level requirements are higher. Illumination levels will also be affected by the size of the items that are being handled. For example, an active area with small items (and small labels on containers) will require 216 to 540 lux (20 to 50 fc) at the working level (work plane). An active area with large items will require only 108 to 216 lux (10 to 20 fc).

In warehouses, the work plane may be vertical (workers may read labels and handle items on vertical shelving units) or horizontal (workers may complete paperwork at document reading height). Adequate levels of vertical illumination are essential to read the labels on cartons and the signs in the facility (including Exit signs), and to drive a forklift.

The best way to determine the required horizontal and vertical illumination levels is to consider the average-to-minimum ratios. The horizontal average-to-minimum ratio for a rack area should not exceed 3:1. If the average light level in an aisle is 215 lux (20 fc), the minimum horizontal level should be 72 lux (6.7 fc) or greater. The vertical average-to-minimum ratio for this same area should not exceed 10:1. This means that if the average lighting level is 160 lux (14.9 fc), the minimum vertical lighting level should never be less than 16 lux (1.5 fc).

Lighting uniformity within a warehouse space is essential. Forklift drivers and others must be able to look up and down the stacks of product without constantly having to adjust their eyes. The human eye functions more comfortably and efficiently when the luminance within the field of vision is fairly uniform.

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Light fixtures with a small element of uplight will help create a more uniform environment. Uplight illuminates the ceiling and eliminates the cavern effect that can occur when a ceiling is dark. With a white or light-coloured ceiling, uplight will bounce off the ceiling to create a more uniformly illuminated environment.

High-bay lighting technology

The most efficient lighting sources suitable for warehouse spaces include high-bay T5 high-output (T5-HO) fluorescent or LED. HID replacement with LED is a common retrofit strategy with savings generally ranging from 40 to 60%.

Lighting control

It is appropriate for lights to remain on constantly in areas that are continually in use. However, savings can be achieved in peripheral aisles that are accessed only part of the time.

- A bi-level switching system can be installed for HID lamps to reduce the input wattage by 50%. Because of the long striking times of HID lamps, they are not suitable for turning on and off through occupancy detection.
- Fluorescent systems, such as T5-HO, may be wired with multiple switching so that the luminaires within certain areas can be turned on and off as needed. This capability increases the system's flexibility and allows the facility to take advantage of skylights and daylight harvesting to reduce operating costs.
- LED fixtures are wired with the diodes together as a single light source. The high-bay fixtures do not have dimming drivers and therefore control-based energy savings are achieved from switching fixtures off. Multi-level lighting control can be achieved by switching alternate fixtures off when the area is not occupied.

For both fluorescent and LED fixtures, automatic control from motion sensing can be accomplished by individual on-board fixture sensors or through remote aisle sensors controlling a group of fixtures.

Daylighting for warehouses

Warehouse spaces are particularly well suited to the use of skylights to provide daylight, since they typically have a large expanse of roof over a single-storey open area. Skylighting has been successfully employed in many warehouse spaces and, with correct design, can save energy.

Lighting measure list (warehouse)
✓ Replace incandescent Exit signs with LED signs
✓ Replace warehouse high-intensity discharge lighting with high-bay fluorescent or LED fixtures
✓ Install daylight sources and lighting control
✓ Install occupancy sensors in warehouse areas

Miller's Home Building Centre in Sauble Beach, Ontario, includes a 2,900-m^2 (31,000-sq. ft.) store and 3,100 m^2 (34,000 sq. ft.) of covered warehouses. In the warehouses, Miller chose **T5 fixtures with electronic ballasts**. In addition to the energy savings – almost 27,500 kWh/year – the T5s are resilient in extreme summer and winter temperatures and stand up well to dust.

Source: Hydro One

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Case in point:
Giant Tiger lighting strategies

Lighting upgrades were among the most common retrofits done at Giant Tiger's Ontario stores. Parking lot lighting was upgraded to LED, MH fixtures were switched to T8 with occupancy sensors, and in-store lighting was changed from 32-W to 25-W bulbs. "Re-lamping with 25-W T8 is a pretty much guaranteed way of saving energy, and the majority of our stores have this," said Mark Pasini, Energy Manager. The payback period ranged from one to three years, depending on the upgrade. "The next step will be moving to an LED T8 tube, such as a 12-W tube. This will also have a significant impact on overall energy reduction. Payback is anticipated to be less than three years with incentives."

- **Replace incandescent Exit signs with LED signs:** Exit signs can be replaced entirely or converted to LED with a retrofit kit. Savings are significant given that Exit signs are on 24 hours, seven days a week.
- **Replace warehouse high-intensity discharge lighting with high-bay fluorescent or LED fixtures:** Replacing quartz MH lighting with T5-HO offers 23% savings, while replacement with high-bay LED can result in savings of 30 to 50%.[17]
- **Install daylight sources and lighting control:** A well-designed daylighting strategy with photosensor lighting controls that switch off fixtures when adequate daylight is available can save significant energy as well as maintenance costs.
- **Install occupancy sensors in warehouse areas:** Warehouse areas can be outfitted with occupancy sensors and multi-level lighting control.

Exterior / parking lot

Exterior lighting is designed for security and safety purposes and is not concerned with the qualities that support colour rendering or detailed visual tasks. As such, LED lighting is well suited for exterior lighting applications.

LED lighting technology has evolved significantly for both new installations and retrofits. With a number of LED lighting manufacturers recently entering the market, a wide selection of retrofit options are available to choose from, including retrofit kits that convert existing fixtures for operation with LED lamps.

Lighting measure list (exterior / parking lot)
✓ Replace building exterior and parking lot lighting with LED lamps
✓ Add photocell and timeclock controls to exterior lighting

- **Replace building exterior and parking lot lighting with LED lamps:** LED fixtures offer savings greater than 40% over conventional HID. Lamps or fixtures can be replaced one-for-one and require minimal design analysis.
- **Add photocell and timeclock controls to exterior lighting:** At a minimum, exterior lighting should be controlled by a photocell that shuts it off during daylit hours. If lighting is not required for security or safety purposes, using timeclocks to shut lights off outside of business hours can also save money and energy. For example, parking lot lighting can be turned on at sunset then off at 10 p.m.; on during early morning hours then off at sunrise. Astrological timeclocks offer enhanced control by automatically adjusting the timer to local sunrise and sunset times for optimal efficiency year round.

[17] High-bay LEDs have a lower light output and may require more fixtures compared to HID for the equivalent illumination.

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Supplemental load reduction

Supplemental load sources are secondary load contributors to energy consumption in buildings (occupants, computers and equipment, the building itself, etc.). These loads can adversely affect heating, cooling and electric loads. However, the effect of supplemental loads can be controlled and reduced through strategic planning, occupant engagement and energy-efficient upgrades. With careful analysis of these sources and their interactions with HVAC systems, heating and cooling equipment size and upgrade costs can be reduced. These upgrades can reduce wasted energy directly, and provide additional HVAC energy savings.

Supplemental loads can be decreased by reducing equipment energy use and by upgrading the building envelope for improved thermal performance.

Power loads and equipment

This section addresses common equipment and devices used within the retail environment, as well as electrical distribution transformers.

Supplemental load measure list (power loads and equipment)
✓ Power off equipment when not in use
✓ Install vending machine controls
✓ Choose ENERGY STAR equipment
✓ Implement an employee energy awareness program
✓ Install high-efficiency transformers

- **Power off equipment when not in use:** The first step in energy savings is turning off equipment and devices when they are not in use. For computers, monitors and point-of-sale terminals, power management settings can be set to automatically power off.
- **Install vending machine controls:** Vending machines are another example of equipment that can be powered down to save energy. Retrofit products are available that use motion sensors to turn machines off when spaces are unoccupied. The machines are powered back up when spaces are in use and at regular intervals to keep their contents cool.
- **Choose ENERGY STAR equipment:** ENERGY STAR-recommended products use 25 to 50% less energy than their traditional counterparts. Computers and other related equipment with the ENERGY STAR label save energy and money by powering down and entering "sleep" mode, or by turning off when not in use, and by operating more efficiently when in use. By purchasing and specifying energy-efficient products, organizations can cut electrical energy use and space cooling loads. Instituting an effective policy can be as easy as asking

For more information about ENERGY STAR products, visit: NRCan's ENERGY STAR in Canada: **nrcan.gc.ca/energy/products/energystar/12519**

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In traditional non-food retail, **refrigeration** is typically not a factor; however, the divide between grocery and non-food retail is shifting, as more stores begin to sell perishable and frozen food in addition to non-food dry goods.

If your store has food refrigeration equipment, consider the following tips:

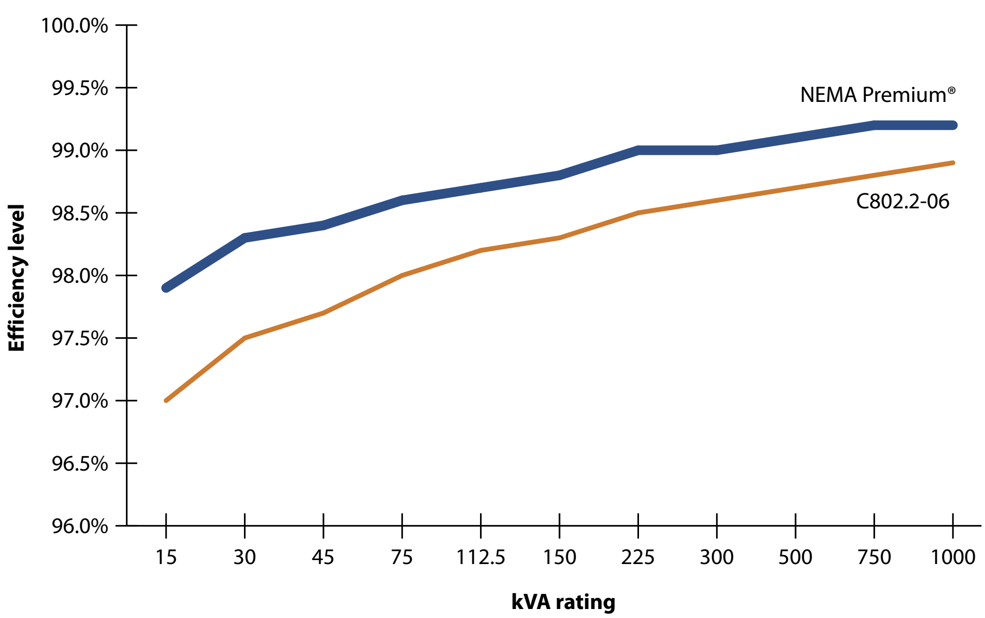
- Install night blinds on open cooling cabinets and ensure that they are closed at night after restocking.
- Avoid overfilling refrigerator shelves to allow air to circulate freely.
- Ensure that door gaskets and seals fit properly.
- Install smart defrost controllers for lower-temperature cases.
- Schedule regular maintenance and cleaning for refrigeration fans, condensers and compressors.

For more information, see the *Major Energy Retrofit Guidelines for Food Stores and Supermarkets*.

procurement staff to specify ENERGY STAR-qualified products such as computers, lighting fixtures and lamps, vending machines, and electronics.

- **Implement an employee energy awareness program:** NRCan's *Implementing an Energy Efficiency Awareness Program*[18] can help owners and managers develop successful employee energy awareness programs. Another useful resource is the *ENERGY STAR Guidelines for Energy Management*.[19] It provides information on creating a communications plan, and ideas, examples and templates that can be customized to help spread the word to employees, customers and stakeholders.
- **Install high-efficiency transformers:** Replace existing transformers at the end of their service life with high-efficiency transformers. In the past several years, there has been an accelerated rate of change to introduce energy efficiency standards for transformers in North America. As a result, manufacturers are offering more efficient transformers that have fewer losses than older models. The new National Electrical Manufacturers Association's (NEMA) premium efficiency transformer designations (CSA C802) require 30% fewer losses than previous regulations. Figure 6 shows the relative efficiencies of standard transformers vs. NEMA premium transformers.

Figure 6. Standard vs. NEMA premium-efficiency levels



The benefits of replacing transformers with energy-efficient models include fewer losses in the electrical transformation and reduction in cooling load for the rooms housing the transformers.

[18] oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/Publications/commercial/pdf/Awareness_Program_e.pdf.

[19] energystar.gov/buildings/about-us/how-can-we-help-you/build-energy-program/guidelines.

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Replacing a single 75-kVA transformer (98% efficient) with a NEMA premium-efficiency transformer (98.6% efficient) reduces the annual transformer losses by approximately 30%, based on 260 days/year, 15% loading for 16 hours/day and 100% loading for 8 hours/day.[20]

Envelope

This section describes options that can be taken to improve the building envelope (roof, walls, foundation, windows and doors). The most common parameters affecting heat flow though the building envelope are conduction, solar radiation and infiltration. Conduction relates to the conductivity of the materials in the envelope assembly and their ability to conduct or resist simple heat flow from hot to cold. Performance is most often represented in RSI-values or R-values (see sidebar), or resistance to flow. Solar radiation brings wanted heat gains through the windows during the heating season and unwanted heat gains during the cooling season. Infiltration relates to air leakage through building elements, such as around windows, doors, envelope intersections, physical penetrations and mechanical openings. Figure 7 shows how heat flows into and out of a building through the envelope.

The RSI (R-Value Système International) value of insulation is a measurement of its thermal resistance.

RSI is presented in $m^2 \cdot K/W$.

R-value is presented in sq. ft.·°F·h/Btu.

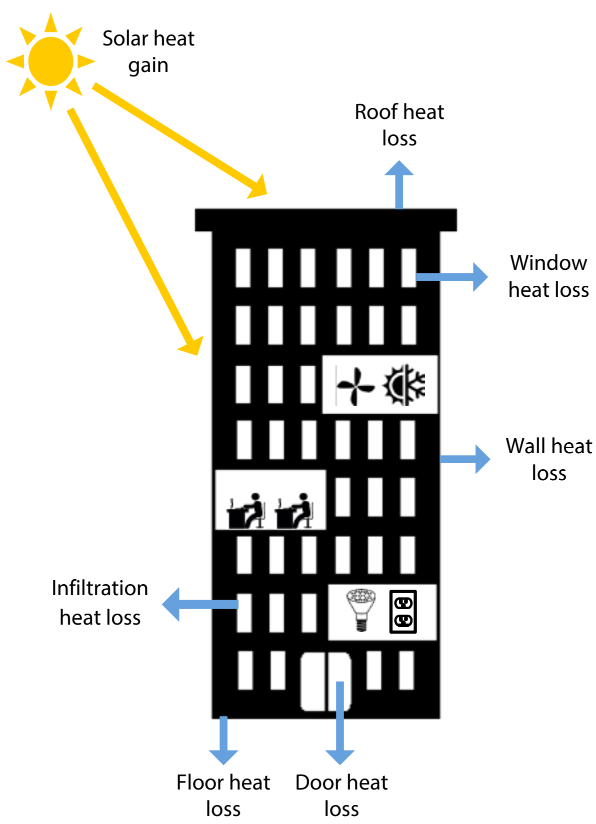
Conversion:

RSI = R ÷ 5.678

R = RSI × 5.678

1 RSI = R-5.678

Figure 7. Building envelope heat transfer



[20] Hammond Power Solutions Energy Savings Calculator, hpstoolbox.com/.

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The ASTM* standard, which is referenced in the 2012 International Energy Conservation Code (IECC) and the International Green Construction Code (IGCC), requires that a building's infiltration rate not exceed 2 L/s per square metre of wall area (0.4 cubic feet per minute per square foot of wall area) at a pressure difference of 75 Pa (0.3 inches water column).

**ASTM, formerly the American Society for Testing and Materials, is an organization that helps develop and deliver international voluntary consensus standards.*

Conduction is largely addressed by the quantity and quality of insulation and the reduction of thermal bridging. Solar radiation is controlled through the solar heat gain coefficient of the windows and/or devices such as window shades, roof overhangs and awnings. Infiltration is addressed through the air barrier and quality of sealing around envelope openings and weather stripping for operable openings (e.g. windows and doors, exhaust/intake dampers when closed, envelope penetrations such as loading docks, etc.).

Supplemental load measure list (envelope)
✓ Reduce infiltration
✓ Add an air barrier
✓ Add insulation
✓ Upgrade windows and doors
✓ Install loading dock seals
✓ Consider a cool roof option
✓ Install high-speed doors and air curtains

- **Reduce infiltration:** Infiltration, or air leakage, is the uncontrolled flow of air through the envelope (either outside air in, or conditioned air out). Although designers understand that the problem exists, they have either largely ignored it, or have accounted for it in the design of the heating and cooling systems.

  Infiltration can also be exacerbated by a positively or negatively pressurized building. The effects of building pressurization will be experienced when a door is opened: a distinct flow of air will be felt either entering or leaving the building. Building pressure should be neutral or very slightly positive. This condition can be verified by an air balancing to measure supply and exhaust air flows. Imbalances can be corrected by addressing the differences between the aggregate supply and exhaust air streams.

  Some signs of infiltration are obvious, such as observed daylight around a closed door; identifying others may require the use of thermographic imagery, which allows for visualization of temperature differentials. Figure 8 demonstrates how infrared imagery can help identify problems related to infiltration or envelope thermal weakness (note the low surface temperature related to parts of the window, window frame, and structural framing around and below the window).

  Smoke pencils are another tool used to identify areas of leakage. When the smoke pencil is held near a potential leak, the movement of the smoke will indicate whether or not there is leakage. The building needs to be pressurized in order for this investigative tool to be effective.

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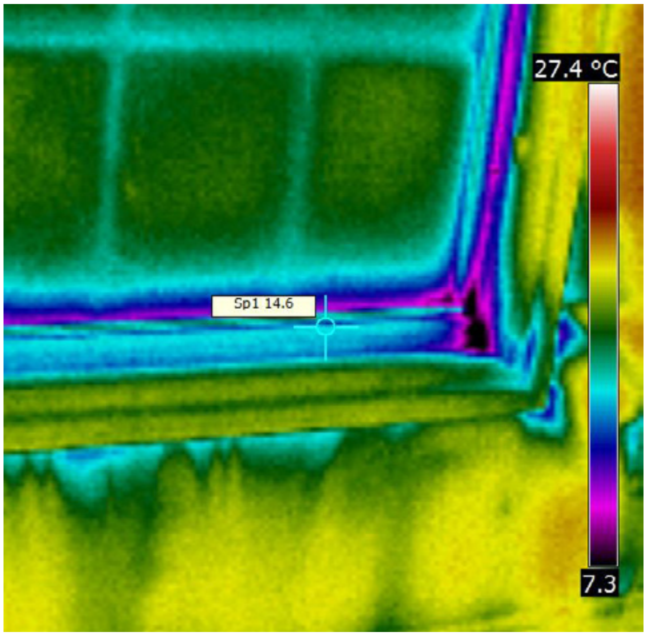
Figure 8. Infrared imagery showing leakage around a window



Infiltration can be exacerbated by stack effect, which is caused by warmer air rising up through the building and escaping though openings at the top of the building. The rising warm air creates a negative pressure at the base of the building, drawing in outdoor air through openings and areas of leakage. The stack effect is reversed during the cooling season, but has a minimal impact when compared to the heating season. The extent of the stack effect is determined by the height of the building, wind speed, and how well the building is sealed near the top. Elevator shafts and stairwells provide a low-resistance path for the rising air, so it is imperative that penetrations such as roof hatches and roof access doors are well sealed.

Fixing air infiltration is usually a low-cost measure, often addressed through the addition or replacement of weather stripping or caulking. Air infiltration can lead to condensation and moisture buildup, and can also be an indication that water is getting into the building envelope. Both of these issues can lead to the formation of mold, and, in some cases, structural damage to envelope components. This additional risk increases the importance of correcting these deficiencies. A building science professional (engineer or architect) should be hired to deliver the envelope diagnostics necessary to properly address all sources of air and water infiltration.

- **Add an air barrier:** Although less obvious than the sources of infiltration outlined above, the presence of an air barrier wrapping the building envelope is an essential component for proper sealing. A properly functioning air barrier system provides protection from air leakage and the diffusion of air due to wind,

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stack effect and pressure differentials caused by mechanically introducing or removing air into or from the building. Buildings that have a properly installed air barrier system can operate efficiently with a smaller HVAC system because the mechanical system does not have to compensate for a leaky building. In some cases, the reduction in mechanical equipment size and cost can offset the cost of the air barrier system. Buildings without air barriers, or with inadequate ones, run the risk of reducing the lifespan of the building envelope, negatively impacting occupant comfort and increasing energy costs.

Air barriers can be applied to a building exterior using several approaches. Combined air/water barrier materials are one of the more common approaches. Mechanically fastened building wraps, self-adhered membranes, and fluid-applied membranes can also be used as air/water barriers for exterior walls.

Fluid-applied air barriers are often preferred for their relative ease of detailing and installation as compared to sheet material. Fluid-applied air/water barriers have long been used in drainable exterior insulation finish systems (EIFSs) and are now becoming increasingly common with other exterior cladding types.

Insulating and adding or improving the continuity of the air barrier has a much greater impact on the energy savings than adding insulation alone. For example, energy modelling of a 5,000-m^2 building in Toronto with a baseline infiltration rate of 7.9 L/s/m^2 (1.55 cfm/sq. ft.) retrofitted with 50 mm (2 inches) of insulation and no improvement to the air barrier saw an energy performance improvement of only 2%. By comparison, adding the same amount of insulation and reducing infiltration to 2.0 L/s/m^2 (0.4 cfm/sq. ft.) led to an energy performance improvement of 12.6%.[21]

- **Add insulation:**

  Roof insulation

  Since a building's roof can be a major source of heat loss and gain, the best way to reduce heat transfer through the roof is by adding insulation. This can be added without interruption to the building occupants and is an option that should be examined when considering a life-cycle replacement of the roof. An energy analysis may show that energy savings are significant enough to warrant an early roof replacement to add the insulation.

  Wall insulation

  Insulation can be added to wall cavities or to the exterior of a building. Exterior-applied insulation is the most common due to the complexity and interruptive nature of insulating from the interior. Furthermore, a continuous layer of insulation outboard of the wall framing has superior performance over non-continuous insulation within the wall cavity. Adding wall insulation is often combined with window replacement, since window openings sometimes need to be "boxed out" to suit the increased depth of the wall assembly.

From a life-cycle perspective, the **best time to increase roof insulation** levels is when the roof needs replacement. This has the advantage of capturing the investment cost in the building's asset management plan and isolating the incremental cost of additional insulation for the energy retrofit cost-benefit analysis.

NECB 2011 minimum wall and roof RSI-values for climate zones 5, 6 and 7:

Zone 5
(e.g. Vancouver, Toronto)
Wall 3.597 $m^2 \cdot K/W$ (R-20)
Roof 5.464 $m^2 \cdot K/W$ (R-31)

Zone 6
(e.g. Ottawa, Montréal)
Wall 4.049 $m^2 \cdot K/W$ (R-23)
Roof 5.464 $m^2 \cdot K/W$ (R-31)

Zone 7A
(e.g. Edmonton)
Wall 4.762 $m^2 \cdot K/W$ (R-27)
Roof 6.173 $m^2 \cdot K/W$ (R-35)

[21] Impacts assessed using an Arborus Consulting in-house energy model.

- **Upgrade windows and doors:**

  Windows

  Windows have an impact on a building's operating costs and on the health, productivity and well-being of occupants. Windows not only have a dominant influence on a building's appearance and interior environment, but can also be one of the most important components impacting energy use and peak electricity demand.

  Heat gain and loss through windows can represent a significant portion of a building's heating and cooling loads. Using natural light can reduce electric lighting loads and enhance the indoor environment. When specifying replacement windows, therefore, both the quality of light they introduce into the building as well as their thermal performance must be considered.

  The rate of heat loss of a window is referred to as the U-factor (or U-value). The lower the U-factor, the greater a window's resistance (RSI-value) to heat flow and the better its insulating properties.

  Windows have the poorest thermal performance of any component in a building's envelope. Even the best windows provide lower RSI-values than the worst walls and roofs. In addition, windows represent a common source of air leakage, making them the largest source of unwanted heat loss and gain in buildings.

Window selection

All of the climate zones in Canada are dominated by heating requirements rather than cooling. As such, your windows should be selected with the following criteria:

- **Minimize heat loss** by selecting the lowest U-value (highest RSI-value) for the entire assembly.
- **Minimize window emissivity** by selecting windows with low emissivity (low-e) in order to minimize heat radiated through the window.
- **Control solar heat gain.** The solar heat gain coefficient (SHGC) can differ depending on orientation to allow beneficial solar gains from one side (e.g. a south-facing wall with an SHGC of 0.6), while limiting solar gains on other sides (e.g. east- and west-facing walls with SHGCs of 0.25) for occupant comfort during the early and later parts of the day.
- **Maximize visible light transmittance**, T_{VIS}, for daylighting.[22]

The text box on page 29 provides a more detailed discussion of each of these criteria, along with a discussion of various window components and assemblies.

[22] The SHGC will influence the resulting T_{VIS}; the lower the SGHC, the lower the T_{VIS}. In other words, increased shading from heat gains lowers the T_{VIS}.

Doors

Doors may be viewed similarly to operable windows, in that they are typically composed of insulating opaque sections and insulating glass units (IGUs), and that there are often significant areas of air leakage between fixed and operable elements. Modern doors offer superior thermal properties and attention to weather stripping.

The NECB prescriptive path requires new buildings to be designed with vestibules and self-closing devices for all regular access doors. Since the energy saving and comfort benefits are applicable to existing buildings, vestibules should be added where feasible.

Figure 9. Loading dock seals

- **Install loading dock seals:** The loading dock opening can be a major source of energy loss, in terms of both heated and cooled air escaping through the doorway. Dock seals and shelters, such as those shown in Figure 9, greatly improve energy conservation, internal temperature, worker environment and merchandise protection from outside elements.

  The majority of dock seals provide an environmental barrier on the top and two sides. The best dock seals include an under-leveler dock seal. The design of standard, pit-mounted dock levelers creates passageways for air infiltration and escape. The concrete pits have small gaps between the edge of the dock leveler and the pit wall, exposing the facility to interior and exterior air flow exchange. Both new and existing pit-style dock levelers can be outfitted with an advanced weather seal system comprising a combination of durable open-cell foam and heavy-duty vinyl cover. This system effectively fills the gaps around the sides and rear of the dock leveler, providing a better seal around the perimeter. For additional protection against energy loss, the underside of steel dock leveler platforms can be coated with spray foam insulation to minimize the platform's ability to conduct heat.

- **Consider a cool roof option:** A "cool roof" reflects the sun's heat away from the roof, rather than transferring it to the building mass. Cool roofs increase occupant comfort by keeping the building cooler during the summer; as a result, air conditioning needs are decreased, which saves air conditioning energy costs. Furthermore, a reflective cool roof experiences less solar loading on the membrane, potentially extending the service life of the roof. However, in a heating-dominated climate, the energy savings from air conditioning may be offset by the loss of beneficial heat gains during the heating season. Results are typically site-dependent based on factors such as roof slope and snow loading. To learn more about cool roofs, visit: coolroofs.org.

- **Install high-speed doors and air curtains:** High-speed doors and air curtains provide climate control for entranceways or warehouse areas that are frequently accessed. Such devices can also provide additional isolation for the loading dock area.

Windows: heat loss

The U-factor of a window may be referenced for the entire window assembly or only the insulated glass unit (IGU). The nationally recognized rating method by the National Fenestration Rating Council (NFRC) is for the whole window, including glazing, frame and spacers. Although centre-of-glass U-factor is also sometimes referenced, it only describes the performance of the glazing without the effects of the frame. Assembly U-factors are higher than centre-of-glass U-factors due to glass edge transmission and limitations in the insulating properties of the frame. High-performance double-pane windows can have U-factors of 1.7 $W/m^2 \cdot K$ (0.30 Btu/hr-sq. ft.·°F) or lower, while some triple-pane windows can achieve U-factors as low as 0.85 $W/m^2 \cdot K$ (0.15 Btu/hr-sq. ft.·°F).

Windows: assembly

Windows can be broken out into two main components: the IGU and the frame.

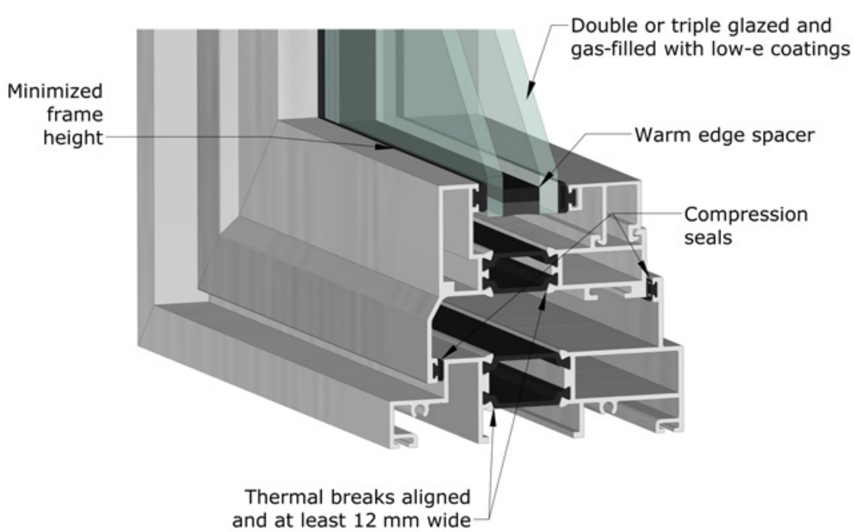
IGU performance is determined by:

- Number of glass panes (double or triple glazed)
- Quality of insulating spacer between glass panes
- Type of coating (such as low-e)
- Type of gas in the sealed glazing unit
- Depth of spacing between the panes of glass

Frame performance is determined by:

- Frame material (conductive or not)
- Thermal conductivity of spacer (thermally broken or not)

Figure 10. Features of an energy-efficient window



Windows: insulating spacers

IGUs generally use metal spacers. They are typically aluminum, which is a poor insulator, and the spacers used in standard edge systems represent a significant thermal bridge or "short circuit" at the IGU edge. This reduces the benefits of improved glazings. "Warm edge spacers," made of insulating material, are an important element of high-performance windows.

Windows: frames

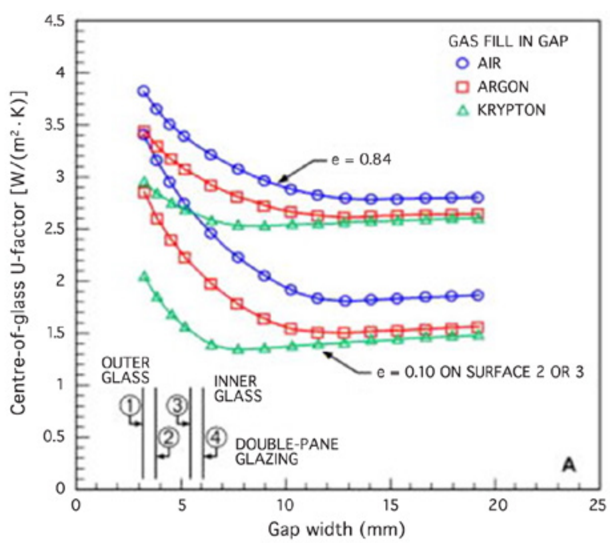
A window's U-factor incorporates the thermal properties of both the frame and the glazing. Since the sash and frame represent approximately 10 to 30% of the total area of the window unit, the frame's properties significantly influence the total window performance.

At a minimum, window frames need to be thermally broken for a cold climate. The overall U-factor of an aluminum frame is improved by almost 50% when thermally broken. Non-metal frames, such as wood, vinyl or fiberglass, can improve the U-factor by 70% due to the non-conductive properties of the material and the option to inject insulating material into the hollow cavities of the frame.

Windows: gas fills

Manufacturers generally use argon or krypton gas fills, with measurable improvement in the thermal performance of the IGU. Both gases are inert, non-toxic, clear and odourless. Krypton has better thermal performance than argon, but is more expensive. Figure 11 plots the relative performance of air, argon and krypton gas fills.

Figure 11. Gas fill thermal peformance



Source: © ASHRAE Handbook – Fundamentals. 2013. ashrae.org

Windows: coatings

Window coatings can have a meaningful impact on building heating and cooling loads. The performance of these coatings is typically discussed in terms of two related metrics: emissivity and solar heat gain coefficient.

> **Emissivity** is the ability of a material to radiate energy. All materials, including windows, emit (or radiate) heat. Reducing a window's emittance can greatly improve its insulating properties.

Standard clear glass has an emittance of 0.84, meaning that it emits 84% of the energy possible and reflects only 16%. By comparison, low-emissivity (low-e) glass coatings can have an emittance as low as 0.04, emitting only 4% of the energy and reflecting 96% of the incident long-wave, infrared radiation. Low emittance reduces heating losses in the winter by reflecting heat back into the building and reduces cooling loads in the summer by reflecting heat away from the building.

> **Solar heat gain coefficient** (SHGC) is a ratio indicating the amount of the sun's heat that can pass through the product (solar gain). The higher the number, the greater the solar gain. The SHGC is a number between 0 and 1. Products with an SHGC of less than 0.30 are considered to have low solar gain, while those with SHGCs above this threshold are considered to have high solar gain.

In a heating-dominated climate, windows with a low SHGC lead to lower cooling loads but higher heating requirements due to the loss of welcomed heat gains in the winter. In some cases, the SHGC may vary depending on the building's orientation. For instance, on the west facade of a building, the SHGC would be designed to be lower than the south facade due to the sun's low angle and higher solar loading during the late afternoon and evening during summer months. This will have a significant impact on occupant comfort along the west facade. Finally, the SHGC will influence the resulting visible light transmittance (T_{VIS}); the lower the SHGC, the lower the T_{VIS}. In other words, increased shading from heat gains lowers the T_{VIS} and resultant opportunity for daylighting.

Windows: emerging advanced technologies

Emerging glazing technologies are now, or will soon be, available. Insulation-filled and evacuated glazings improve heat transfer by lowering U-factors. Switchable glazings, such as electrochromics, change properties dynamically to control solar heat gain, daylight, glare and view. Integrated photovoltaic solar collectors involving window systems that generate energy can also form part of the building envelope.

> **Recommendation:** To determine which window specifications will deliver the greatest energy savings and occupant comfort, a whole-building energy model is recommended. Once the building geometry, thermal properties and systems configuration are populated in the model, different window specifications can then be tested. Contact an experienced energy modeller to work with you on this analysis.

PART 1

Air distribution systems upgrade

The HVAC system regulates the temperature, humidity, quality and movement of air in buildings, making it a critical system for occupant comfort, health and productivity.

Rooftop units (RTUs) are the main type of system used to distribute and condition air in non-food retail stores. The lowest cost option to reduce RTU energy is to expand the allowable ranges for indoor temperature and humidity, i.e. allowing temperature and humidity levels to rise during the summer months and lower during the winter. By carefully studying the thermal comfort needs of the occupants in each space type, you can determine the acceptable range for temperature and humidity. These comfort ranges can be found in ASHRAE Standard 55.[23]

ASHRAE Standard 55 comfort range example

Acceptable temperature and humidity ranges depend on activity levels and clothing. Retail environment occupants are expected to have metabolic activity levels ranging from 1.4 (standing) to 1.7 (walking around). Clothing will be highly variable, depending on the season. For this example, an average of 0.61 clo (e.g. trousers and long-sleeved shirt) is assumed.

At 50% relative humidity and a metabolic rate of 1.4, the comfortable temperature range is between roughly 17.4 and 24.5 °C. At a metabolic rate of 1.7, the comfortable temperature range is between roughly 13.5 and 21.5 °C. Given the combined activity levels, a reasonable comfortable temperature range is between roughly 17.4 and 21.5 °C.

You should also consider the indoor air quality and the amount of ventilation air required by building occupants in each space type. Conditioning outside air is one of the most energy-intensive loads that the RTU faces, so your first step should be to minimize the amount of outside air that needs to be conditioned. Calculate the required exhaust and ventilation air according to ASHRAE Standard 62.1,[24] using the default occupancies provided in the standard. Then apply demand control using CO_2 as a proxy for actual occupancy. CO_2 can be metered at the return duct to the RTU with the control system providing a reset signal to the outdoor air damper to open or close according to the CO_2 in the space.

[23] *Thermal Environmental Conditions for Human Occupancy*. ashrae.org/resources--publications/bookstore/standard-55.

[24] *Ventilation for Acceptable Indoor Air Quality*. ashrae.org/resources--publications/bookstore/standards-62-1--62-2.

PART 1

Air distribution systems measure list
✓ Start with first-order measures
✓ Install high-induction swirl diffusers
✓ Eliminate heating in front entrance vestibule
✓ Use demand control ventilation
✓ Install destratification fans in warehouses

- **Start with first-order measures:** The first-order measures are designed to reduce the load at the zone level with the intent of reducing requirements on the air handler and supporting heating and cooling systems. Optimizing space conditions and performance at the zone level balances occupants' needs with the need to minimize the energy required to deliver comfortable conditions. An existing building commissioning (EBCx) program is often the first step in this optimization.

  The assessment phase of an EBCx program involves collecting configuration and operational conditions of a building's air handling systems. Thermostat settings, operational schedules and damper operations are examples of elements that would be confirmed and documented in the initial commissioning report, along with any deficiencies requiring correction during the implementation phase.

  Refer to the **Existing building commissioning stage** for a list of potential operational measures.

- **Install high-induction swirl diffusers:** Displacement ventilation is a method of delivering fresh air to occupants near the floor of a space and returning air at a high level. Instead of maintaining design conditions in the whole room, displacement ventilation systems condition air where it is needed, in the occupied zone, thus saving energy required to condition the entire space.

  High-induction swirl diffusers offer benefits similar to displacement ventilation, but are better suited to retail environments because air is delivered from the ceiling. The high-induction air flow from the swirl supply diffusers creates an air distribution pattern that directs the conditioned air to the occupant zone. The result is better air mixing and reduced stratification that enhances indoor air quality and delivers energy savings.

- **Eliminate heating in front entrance vestibule:** Many retail buildings have a vestibule at the main entrance to minimize air infiltration. Although vestibules are intended to be passage spaces, many vestibules are heated, effectively making them conditioned spaces. Energy savings can be realized by removing the heat from vestibules, and restoring them to their original purpose as transitions between the outdoors and the interior conditioned space.

PART 1

Demand control ventilation

In just four months, Canadian Tire installed DCV systems in 129 of its Ontario stores.

Outside peak shopping hours, when fewer customers are in the stores, the CO_2 monitors detect a change in occupancy and reduce the volume of ventilation air being delivered by the RTUs. This lowers energy consumption while maintaining indoor air quality.

Annual electricity and natural gas savings are expected to be more than 2,500,000 kWh and 2,000,000 m^3, respectively.

Source: SaveONenergy

Ideally, vestibules should be designed so that the interior and exterior doors do not need to be open at the same time for passage. In cases where interior and exterior doors will be simultaneously open, an air curtain can be used to provide a barrier from the unconditioned outdoor air.

- **Use demand control ventilation (DCV):** Retail buildings have highly variable occupancy rates with extended operating hours. Ventilation systems are typically designed for the maximum occupancy, which occurs only occasionally. This results in an over-ventilated building during the majority of its operating hours. In order to avoid the energy penalty from over-ventilation, a DCV system is recommended.

  DCV ensures that a building is adequately ventilated while minimizing outdoor air flows. Typically, sensors are used to continuously monitor CO_2 levels in the conditioned space, allowing the RTU to modulate the outdoor air ventilation rate to match the demand established by the occupancy needs of the space or zone (CO_2 is considered a proxy for the level of occupancy; the higher the CO_2, the more people in the space and therefore the more outdoor air required.)

  Economizer controls should always override DCV in control sequences.

- **Install destratification fans in warehouses:** Destratification saves heating energy by bringing heat down to floor level where it is needed to keep occupants comfortable. Mixing the air also reduces ceiling temperatures, which reduces heat losses through the roof.

  Cooling energy is also saved due to the movement of large masses of air at the right speed for the evaporative cooling effect of 3.3 to 4.4 °C (6 to 8 °F). As a result, thermostats can be set higher; up to 8 °C (15 °F) warmer without compromising comfort.

  Two types of fans are highly effective for destratifying high ceiling spaces.

  High-volume, low-speed (HVLS) warehouse fans are considered air movement systems, not just cooling systems. They move and mix large volumes of air, and they do so very efficiently. As a result of the masses of air they move, they are very effective in aiding cooling, heating (through heat destratification) and ventilation.

  HVLS fans are typically 2.4 to 7.3 m (8 to 24 ft.) in diameter to move large volumes of air at very low speeds. This creates a gentle but significant air flow that has an immediate cooling effect in a hot room. A 7.3-m (24-ft.) fan can move up to 177,830 litres of air per second (376,804 cubic feet per minute). Ideally, an HVLS fan will send a column of air down and out 360° toward the walls, back up to the ceiling and back through the fan. That pattern, known as floor jet circulation, naturally exchanges the air in very large spaces.

  Ceiling-mounted air turbines are more compact than HVLS fans and provide effective destratification.

PART 1

The importance of destratification

Destratification can be used throughout the heating season to save energy in large rooms. It is well known that warm air rises, and in spaces with high ceilings, it is not uncommon to find air temperatures at the top of the space, near the roof, that are 10 to 30 °C higher than the temperature at the floor.

The formula for heat loss through the roof is:
$Q = (1/RSI) \times A \times (T_{in} - T_{out})$, where RSI represents the level of insulation, A represents the roof area and $(T_{in} - T_{out})$ represents the temperature difference between the interior and exterior.

Since the insulation levels (RSI) and roof area (A) are fixed, the amount of heat loss through the roof is a function of the temperature difference between the interior and exterior $(T_{in} - T_{out})$. Therefore, if space temperatures are highly stratified during the heating season, the space ends up being significantly overheated to maintain desirable temperatures in the occupied zone.

The following example demonstrates how the rate of heat loss changes depending on the space temperature near the ceiling. In this example, the space has a roof area of 2,500 m^2 and a roof RSI-value of 5.46 (R-31).

Case #1: without destratification

Outdoor temperature = -10 °C
Ceiling temperature = 30 °C

Q = 1/5.46 x 2,500 x [30 – (-10)]
= 458 x (40) = 18,315 W

Case #2: with destratification

Outdoor temperature = -10 °C
Ceiling temperature = 15 °C

Q = 1/5.46 x 2,500 x [15 – (-10)]
= 458 x (25) = 11,450 W

Heat loss through the roof is reduced by 37% by lowering the ceiling temperature 15 °C, or in other words, 37% less heat is required to maintain the same space temperature in the occupied zone. Additional savings will result from a reduction in heat loss through the upper part of the walls.

PART 1

Enclosed malls

Enclosed shopping malls present a number of unique challenges compared to other non-food retail building types.

While other non-food retail subsectors predominantly use packaged HVAC equipment, shopping malls typically employ central HVAC equipment, including boilers, chillers and air/water distribution systems, which are often controlled by sophisticated building automation systems (BAS).

Shopping malls also typically include significant common areas (e.g. corridors, entranceways, and atriums) with unique lighting and HVAC requirements.

In addition, there is significant energy use in many shopping malls to support ancillary services such as food courts or parking garages.

Heating and cooling resizing and replacement

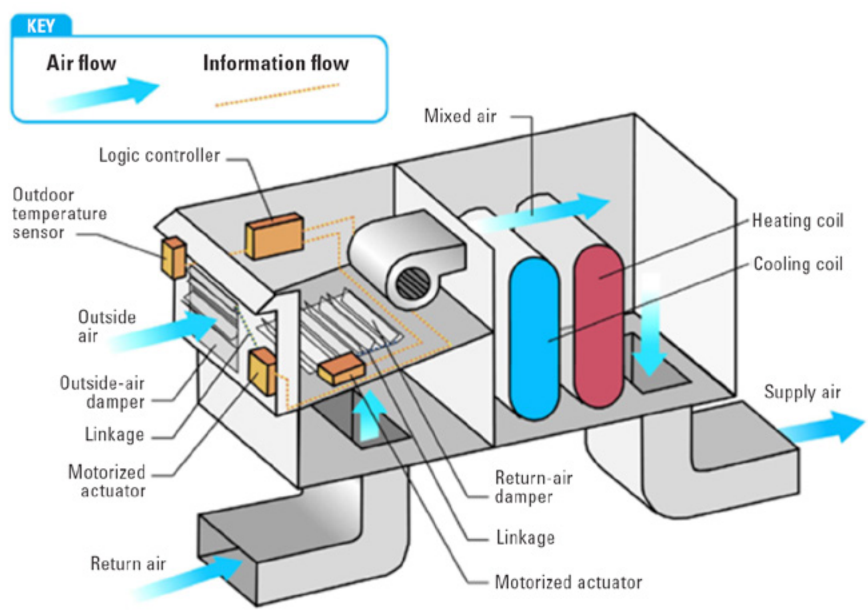
This section covers heating and cooling equipment, including RTUs, warehouse heaters and domestic hot water systems.

In keeping with the staged approach to retrofits, heating and cooling equipment can take advantage of load reductions achieved in earlier stages. Not only will the heating and cooling systems benefit from improved equipment efficiencies, but the system capacities may also be reduced, yielding even greater energy savings. Furthermore, many existing systems are oversized to begin with, so it may be possible to justify replacing the current system with a properly sized one, or retrofitting it to operate more efficiently.

Rooftop units

More than a third of Canadian commercial/institutional building floor space is conditioned by self-contained, packaged rooftop units.[25] RTUs are typically configured with natural gas combustion or electric duct heaters for heating and direct expansion (DX) refrigeration cooling. In some cases, heat recovery wheels or cores are included as well. The RTU may also be configured as a heat pump or, in rare cases, the RTU heating may be delivered through a hot water coil served by a central boiler plant. In addition, units may be constant volume or variable volume. A typical RTU setup is shown in Figure 12.

Figure 12. Typical RTU



Source: U.S. EPA

[25] Natural Resources Canada. Commercial and Institutional Building Energy Use Survey 2000.

PART 1

RTU efficiencies have improved dramatically over the past 15 years, and there are control-based retrofit technology options available that can deliver savings in excess of 50%. Depending on the efficiency and age of the RTU, there is a business case for complete replacement or retrofit upgrades. For instance, if the RTU is 15 years (the expected service life) or older, replacement is probably the better option. If the RTU is only 5 years old, retrofitting may be a viable option.

The heating efficiency of older existing RTUs may range from 60 to 75%, while new RTUs can achieve greater than 80% efficiency for non-condensing units, and upwards of 90% efficiency for condensing units.

Note: 1 ton of cooling capacity = 3.5 kW or 12,000 Btu/hr

Table 2 illustrates how ASHRAE's cooling efficiency standards have evolved.

Table 2. Evolution of RTU efficiency standards

90.1-1999	90.1-2000	90.1-2004	90.1-2010		CEE Tier II		RTU challenge
EER	EER	EER	EER	IEER	EER	IEER	IEER
8.7	10.1	10.1	11.0	11.2	12.0	13.8	18.0

The following cooling efficiency metrics for RTUs are defined by the Air-Conditioning and Refrigeration Institute (ARI), a trade association representing air conditioner manufacturers:

- Energy efficiency ratio (EER), defined as the rate of cooling in Btu/hour divided by the power input in watts at full-load conditions, is a measure of full-load efficiency. The power input includes all inputs to compressors, fan motors and controls.
- Integrated energy efficiency ratio (IEER), defined as the cooling part-load efficiency on the basis of weighted operation at various load capacities, applies to RTUs with cooling capacities equal to or greater than 19 kW (5.4 tons).
- Seasonal energy efficiency ratio (SEER) describes the seasonally adjusted rating based on representative residential loads, unlike EER, which describes the efficiency at a single rating point. SEER applies only to RTUs with a cooling capacity of less than 19 kW. Although units less than 19 kW that use three-phase power are classified as commercial, they still use the residential SEER metric. This is because these small units are similar to the single-phase units used in residential applications, which have a large part of the market share in this size range. Older units of less than 19 kW often have a SEER rating as low as 6.

The Consortium for Energy Efficiency (CEE), a non-profit organization that promotes the adoption of energy-efficient technologies, defined the 1993 Tier 1 minimum efficiency recommendation as having an EER of at least 10.3, 9.7 and 9.5, respectively, for the small, large, and very large RTU size categories.

PART 1

Replacing RTUs

At some of its stores, Giant Tiger replaced older CV packaged RTUs with new high-efficiency units with variable speed supply fan motor, economizer and demand control ventilation using CO_2.

"For this type of retrofit measure, we often try to right-size the equipment because equipment tends to be oversized in the small store retail market," said Mark Pasini, Energy Manager. "The payback can be quite attractive when considering the incentives and potential savings."

Under the U.S. Department of Energy's Rooftop Campaign, which promotes adoption of efficient RTUs, efficiency specifications have increased to a minimum IEER of 18 for units 35 to 70 kW (10 to 20 tons) as a challenge to manufacturers. The industry has responded favourably, and a number of manufacturers now have units that meet this aggressive target, many of which are available in the Canadian market.

Heating and cooling measure list (rooftop units)
✓ Convert constant volume system into variable flow system with demand control and economizer
✓ Add compressor control to reduce runtime
✓ Add economizer damper
✓ Add heat or energy recovery
✓ Replace rooftop units

Retrofitting RTUs for energy savings usually takes the form of controls, rather than adding energy saving equipment (such as heat recovery) or motor replacement. However, opportunities do exist to add energy saving equipment in some cases. Under the **retrofit** category, the following four measures are applicable:

- **Convert constant volume system into variable flow system with demand control and economizer:** In the current market, there are two packaged technologies that have been recognized by utilities as acceptable for conservation incentive programs. For constant volume RTUs greater than 26 kW (7.5 tons), a fully packaged advanced rooftop controller retrofit package that converts a CV system into a variable flow system with demand control and economizer is available. A field study by the Pacific Northwest National Laboratory[26] provided independent analysis of this technology, with results showing a reduction in normalized annual RTU energy consumption between 22 and 90%, with an average of 57% for all RTUs.
- **Add compressor control to reduce runtime:** For RTUs smaller than 26 kW, packaged controllers that reduce air conditioning energy are available. These devices control the compressor cycles to reduce the runtime, while continuing to deliver the cooling expected from the unit. Typical air conditioning systems are designed to meet the peak load conditions, plus a safety margin, and operate continuously until the room's thermostat set point temperature is reached. However, under most operational conditions, maximum output is not required, and the system is oversized for the load. Simple controllers that detect thermodynamic saturation of the heat exchanger turn off the compressor to avoid overcooling. Industry experience has shown an average of 20% cooling energy savings.

[26] Advanced Rooftop Control (ARC) Retrofit: Field-Test Results. pnnl.gov/publications/abstracts.asp?report=474340.

PART 1

- **Add economizer damper:** Some RTU models can accommodate an economizing damper as a manufacturer's option. In cases where the economizer damper wasn't included in the original product selection, adding the economizer will deliver energy savings.

- **Add heat or energy recovery:** Similarly, some RTU models can accommodate heat or energy recovery ventilators as a manufacturer's option. In cases where these options were not included in the original product selection, adding them will deliver energy savings.

  There is often a favourable business case for **replacement** of existing RTUs with new high-efficiency units. With the potential for combined heating and cooling savings of 50% or more, it can sometimes be cost effective to replace an RTU before the end of the equipment's expected life span.

- **Replace rooftop units:** Replacing an existing RTU will bring numerous efficiency gains, especially where high-efficiency units are specified with variable speed fans and compressors, energy recovery and condensing gas combustion. RTUs are sized according to their cooling capacity (kW or tons), with nominal heating capacities set according to the cooling capacity. Careful attention to product specifications is required to identify high-efficiency gas combustion options. Replacing an existing RTU with a new generation advanced RTU will bring numerous efficiency gains and increased occupant comfort through better control. Significant advances in the performance of RTUs have been made since 2011. Furthermore, when considering replacement, the equipment size should be revisited to ensure right-sizing. Some of the features available with the new generation advanced RTUs include:
  - Insulated cabinets for improved energy efficiency and acoustics
  - Multi-staged or modulating heating control with turndown ratio of 10:1
  - Condensing type heating with annual fuel utilization efficiency (AFUE) up to 94%
  - Variable speed electronically commutated fan motors
  - Variable speed scroll compressors with superior part-load efficiency
  - Heat and energy recovery from exhaust air
  - Demand controlled ventilation using CO_2 sensors
  - Heat pump option
  - SEER up to 18; IEER up to 21
  - Remote energy monitoring and operational supervision

The Pacific Northwest National Laboratory (PNNL) has created a **Rooftop Unit Comparison Calculator** (**www.pnnl.gov/uac/costestimator/main.stm**) that compares high-efficiency equipment with standard equipment in terms of life-cycle cost.

This online screening tool provides estimates of life-cycle cost, simple payback, return on investment and savings-to-investment ratio. The simulations use U.S. locations for weather; however, for Canadian locations with the same climate zones, the tool may provide a reasonable estimate of the cost-benefit analysis.

Warehouse heating

This section addresses warehouse heating equipment.

Heating and cooling measure list (warehouse heating)
✓ Install infrared heaters
✓ Install direct-fired, high temperature rise blow-through space heaters

- **Install infrared heaters:** Infrared energy warms people, floors, walls, and other surfaces directly without heating the air first. The result is a warming effect, similar to the effect felt from the sun on a chilly day. When infrared heating is used in an enclosed building, objects in the space absorb the emitted infrared energy. Once absorbed, the energy is converted into heat that in turn warms the surrounding air. Alternatively, with forced-air systems, the air must first be heated and then circulated in order to warm objects and people in the space.

  The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has found that infrared heaters can reduce the required heat needed to maintain a comfortable temperature in a building (heat load) by at least 15%.[27] The savings are the result of providing focused warmth where it is needed, rather than heating the air in the entire space.

  Radiant heaters can also work efficiently to heat areas where doors are opened and closed often, like a loading dock. When the door is opened, the warm air in the space will quickly escape to the outside, but a radiant heater will continue to provide comfort heating to the occupants in areas served by the heater.

- **Install direct-fired, high temperature rise blow-through space heaters:** Direct-fired, blow-through space heaters save energy and improve thermal comfort and indoor air quality. These heaters bring make-up air into the warehouse and condition it with burners located downstream of the blower, making them very effective in high-ceilinged warehouse spaces with mechanical exhaust systems. Energy savings of 35 to 38% can be achieved compared to the ASHRAE Standard 90.1 baseline heating system (an indirect-fired boiler supplying reheat to a variable air volume system).[28] Benefits include:
  - Combustion and thermal efficiencies of 100% and 92%, respectively
  - Quick response to load changes, such as open loading dock doors, thanks to high temperature rise capabilities
  - High mixing induction ratios that minimize air temperature stratification

[27] *2008 ASHRAE® Handbook: Heating, Ventilating, and Air-Conditioning Systems and Equipment*, Chapter 15, pg. 15.1, "Energy Conservation," 2008, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

[28] Cambridge Engineering Inc. white paper "Energy Modeling Warehouse Heating Systems," thomasnet.com/white-papers/abstract/101409/energy-modeling-warehouse-heating-systems.html.

PART 1

Domestic hot water

Although water heating comprises only a small portion of the total energy use in Canadian non-food retail stores (~3%), there are a number of opportunities to save energy.

Heating and cooling measure list (domestic hot water)
✓ Install low-flow aerators
✓ Replace existing heater with more efficient unit
✓ Replace storage-based system with on-demand

- **Install low-flow aerators:** Reduced flow through faucets reduces the consumption of hot water. Installing water-efficient fixtures is the lowest cost measure to reduce energy, and replacements can be easily done by operations staff. Products are available that deliver flow rates as low as 0.95 L/min.
- **Replace existing heater with more efficient unit:** Existing hot water heaters more than 20 years old operate at efficiencies of 60 to 80%. They can be replaced with new units that achieve efficiencies as high as 95% when condensing.
- **Replace storage-based system with on-demand:** In smaller buildings with fewer washrooms, it may be possible to replace a central water heater with an electric on-demand heater near the point of use, or a central gas-fired on-demand heater. On-demand water heaters are tankless, heating the water as it passes through the heat exchanger. These types of heaters are about 20% more efficient than gas-fired tank type heaters,[29,30] and the savings are attributed to a lack of storage losses in conventional tank systems.

  On-demand water heaters come in two basic types. Small electric units that mount close to the point of use are very useful when there are only one or two lavatories. Larger, centralized gas-fired units are more applicable for multiple lavatories. On-demand water heaters are typically more expensive than the storage type, and a full cost-of-ownership analysis would be useful to determine if there is an economic benefit.

Although uncommon in non-food retail, if your building has shower facilities, consider installing **low-flow showerheads**. Products are available that deliver flow rates as low as 4.7 L/min.

[29] ENERGY STAR. ENERGY STAR Certified Water Heaters. energystar.gov/productfinder/product/certified-water-heaters/results.

[30] Natural Resources Canada, Office of Energy Efficiency. Energy Efficiency Ratings. Water heaters, gas. oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=WATERHEATER_G.

PART 1

IMPORTANT: Managing Legionella in hot and cold water systems

Legionella bacteria are commonly found in water and can multiply where nutrients are available and water temperatures are between 20 and 45 °C. The bacteria remain dormant below 20 °C and do not survive above 60 °C. Legionnaires' disease is a potentially fatal type of pneumonia, contracted by inhaling airborne water droplets containing viable Legionella bacteria.

Risk from Legionella can be controlled through water temperature. Hot water storage should store water at 60 °C or higher. Hot water should be distributed at 50 °C or higher (using thermostatic mixer valves at the faucet to prevent scalding). These temperature criteria should be respected when designing any retrofits to your domestic hot water system.

See the American Society of Plumbing Engineers (ASPE) 2005 Data Book – Vol.2, Ch.6 – Domestic Water Heating Systems Fundamentals for more details.

Natural Resources Canada offers a wealth of resources and guidance to help you improve the energy efficiency of your buildings.

- *Recommissioning Guide for Building Owners and Managers*
- *Energy Management Best Practices Guide*
- *Energy Management Training Primer*
- *Improve Your Building's Energy Performance: Energy Benchmarking Primer*
- *Energy benchmarking*

For these and other resources, visit our website at **nrcan.gc.ca/energy/efficiency/eefb/buildings/13556**

Email: **info.services@nrcan-rncan.gc.ca**

Toll-free: 1-877-360-5500

SEARS CANADA: A CASE STUDY

PART 2

The winner of Natural Resources Canada's ENERGY STAR Retailer of the Year[31] award six years in a row shows how energy upgrades benefit its triple bottom line.

> "Energy efficiency sends a positive message to our customers and associates, and we believe these initiatives are in keeping with our vision, mission and values."
>
> – Greg Paliouras, Divisional Vice-President, Construction, Energy & Maintenance

Energy efficiency upgrades completed between 2007 and 2013 have reduced Sears Canada's overall energy use by more than 23%.

Photo courtesy of Sears Canada

Sears Canada has been a trusted name in retail for more than 60 years, with approximately 200 retail department and Sears Home stores.

Its commitment to sustainability is a key part of the company's approach to achieving success on economic, environmental and social fronts. Cutting energy reduces costs and the company's environmental impact, while its Live Green program helps customers reduce their energy bills and store associates to spot energy saving opportunities.

"Without senior management's awareness and support, we wouldn't have been able to do energy efficiency projects," said Paliouras. "The process requires transparency and follow-through. Energy updates are the first item I review with my Senior Vice-President at our regular one-on-one meetings. "

Sears Canada met its goal of reducing greenhouse gas emissions from its retail operations by 20% below 2007 levels by 2013 — a year ahead of schedule. It is now aiming to cut emissions in half by 2020.

[31] The ENERGY STAR Retailer of the Year award is part of NRCan's Market Transformation Awards. nrcan.gc.ca/energy/products/for-participants/awards/13524.

PART 2

"Our retrofit process is part of our capital plan, which includes energy and maintenance, so we focus on the building envelope and making sure we do what needs to be done to maintain those buildings."

— Greg Paliouras

Major benefits

- ✓ Between 2007 and 2013, Sears Canada cut its total energy use by 23.2% (electricity by 32.5% and natural gas by 8%).
- ✓ Associated greenhouse gas emission reductions amount to more than 11,200 tonnes.
- ✓ Its LED lighting retrofit—the largest in North America at the time — cost approximately $4.5 million and has led to annual savings of about $2 million.
- ✓ Sears Canada Live Green teams generate new energy efficiency ideas and solutions as well as help monitor stores' energy performance.

A made-in-Canada approach to retrofits

Paliouras said that Sears Canada used a staged approach spanning the past decade for its retrofits, but that the process developed more from opportunity and necessity than by design.

Comparing the energy performance of Canadian stores to U.S. ones, for example, was not a viable option. U.S. stores use far less accent lighting — which accounts for a large part of Sears Canada's energy use — than Canadian stores.

"Elements such as weather and our more significant use of spotlights in retail stores and the unique lighting requirements needed for our Sears Homes stores meant that we had to develop a made-in-Canada solution," said Paliouras.

Similarly, energy audits were not always as useful as they might have liked. "They tended to confirm information we already had. We knew that HVAC and lighting make up 90% of our energy consumption, so we addressed those areas."

They started looking for energy reduction opportunities using building automation systems (BAS), which had been installed in 90% of Sears Canada stores in the early 2000s. "With those controls we were able to find opportunities, like adding variable frequency or speed drives, and those were installed in numerous buildings."

PART 2

What was done?

Lighting

Among its many lighting retrofits, outlined below, Sears Canada completed the largest roll-out of LEDs in North America in 2011, replacing more than 100,000 incandescent spotlights. Wayne Prada, Project Director, Energy and Environmental, explained that the LEDs they needed didn't even exist at the time. "We specified a quality of light and worked with vendors to produce them for us."

Sears Canada tested more than 16 makes and manufacturers, issued two requests for proposals and piloted entire stores with the shortlisted products to ensure the best fit. "We looked at store metrics, reviewed customer and associate feedback, and conducted executive walk-throughs before deciding on the right bulb," said Paliouras.

Lighting type	Year	Electricity reduction (kwh)
T12-T8 conversions	2007-2008	14,000,000
Replace 90-W incandescents with 60-W	2008	13,000,000
Replace 60-W incandescents with 15-W LEDs	2011	22,000,000
Replace 28-W T8s with new 25-W T8s	2012	8,000,000
Distribution centre lighting upgrades	2008-2014	1,200,000
Headquarters building/outlet store T8 fluorescent retrofits	2008-2014	610,000
Other projects (metal halide conversions, exterior sign LED retrofits, etc.)	2007-2014	2,000,000
Total electricity savings (excludes estimated HVAC savings):	**60,810,000 kWh**	

"Our LED vendor partner was quite pleased with the final solution because it gave them a lot of business. All they have to say to prospective customers is 'Look at Sears'."

— Greg Paliouras

Building controls, HVAC and envelope

BAS are in place in almost all Sears Canada buildings. Lighting, heating and air conditioning controls are all preset to turn on and off at particular times, and facility leads and regional field managers regularly review the settings to ensure that they are operating efficiently and to look for anomalies. This information allows them to compare their respective stores with ones of a similar age, function and construction and pinpoint other savings opportunities.

In about 50 stores, the HVAC equipment was retrofitted with new variable frequency drives and numerous rooftop air handling units have been replaced.

PART 2

Sears Canada is also responsible for roof replacement in the majority of its leased and owned stores. Its active replacement program includes adding proper insulation on top of buildings and minimizing the impact of outdoor weather inside the stores.

Energy awareness and training

Since 2009, Sears Canada's Live Green teams have received monthly updates on sustainability programs, including tips to reduce their buildings' carbon footprints. Under the program, associates monitor energy use and provide feedback to ensure that all systems are working efficiently.

> Wayne Prada lives green. An admitted early adopter, he said that when he switched lighting in his house to LEDs, rather than recycle his old compact fluorescent lamps, he brought them to work and used them to switch out incandescent desk lamps.

"Most of our national logistics facilities went through ISO 14001 certification and built in energy management as part of their review cycle," explained Katie Harper, Director, Sustainable Operations. "Energy and waste performance are discussed regularly and compared to their five-year average."

At one of Sears Canada's largest logistics centres, in Vaughan, Ontario, employees took over an entire wall to showcase their energy reductions and green initiatives. A board at the entrance to the warehouse shows the facility's energy consumption and how it compares to the previous year. They also track energy consumption and report on it at monthly management meetings.

"We wanted to give associates a sense that they could play a part in saving energy," said Harper. "Most of us don't have direct control over our buildings' energy management settings, so we highlighted actions like keeping dock doors closed, turning off lights, anything where they can have a direct impact."

Paliouras agreed: "Our focus has been on awareness of how energy is used — and can be saved — at work and at home. We believe that associates who understand how energy is used are more likely to avoid energy-wasting behaviours."

At the Sears Canada Vaughn logistics centre. L-R: Frank Vessio, Logistics Support Manager, Katie Harper, Wayne Prada and Greg Paliouras.

Photo courtesy of Sears Canada

Monitoring

Energy consumption is monitored primarily through utility bills that are uploaded by a payment vendor to a web portal and compared to historic averages and trends as well as weather anomalies.

"If an anomaly is detected, we look deeper into the site's energy profile using the BAS and will also conduct random checks on a weekly basis to identify any sites that have deviated from standard protocols," explains Paliouras.

In the future, Sears Canada plans to continue its exterior lighting upgrades and HVAC and roof replacement programs, and will conduct a full BAS recommissioning program to maximize efficiencies. It is also currently reviewing new fluorescent prototypes for stores.

How were the retrofits financed?

Retrofits like these are part of Sears Canada's capital planning process for building maintenance. "Each project has to stand on its own. The business case has to be there," said Paliouras. "Just because we're able to save on energy does not mean we would favour an energy retrofit over another initiative that would service our customers in a more significant way."

Some of their retrofit initiatives have also received provincial utility incentives. The Ontario Power Authority's **SaveOnEnergy** program, for example, provided $775,000 in incentives for Sears Canada's LED lighting retrofit.

Challenges and advice

The greatest challenge that Sears Canada has faced is the sheer diversity of its building portfolio. Buildings range in age from 5 to 60 years, and in size from about 2,800 m^2 (30,000 sq. ft.) up to more than 185,000 m^2 (2 million sq. ft.).

"We have yet to overcome this inconsistency completely, but we've seen success by using our business case methodology to get projects approved and implemented," said Paliouras. "This allows us to perform our due diligence in evaluating multiple technologies and make the case that an investment will have a financial benefit and will not impact the delivery of goods and services to our customers."

His advice to other retailers considering similar retrofits? Test and pilot new technologies thoroughly, see samples, and talk to multiple vendors. Investigating new LED manufacturers and pilot testing their use, for example, took two years to complete.

"We had heard stories about some facilities using LEDs from an unproven brand, and they experienced rapid lumen depreciation, which resulted in light levels that were unacceptable," said Prada. "The end result of our process proved that we made the right choices."

PART 3

MY FACILITY

The following take-away section provides a summary of the retrofit measures applicable to non-food retail stores in the form of a questionnaire. This tool complements ENERGY STAR Portfolio Manager by providing direction on how to set improvement goals based on your site energy use intensity (EUI); an ENERGY STAR score is not currently available for Canadian non-food retail stores.

The appropriate next steps for your facility will vary depending on your EUI:

- If your facility has a site EUI **above the national median**, you are likely a good candidate for a major retrofit **investment**. Investing in major retrofits and undertaking a staged approach will likely have the greatest impact on your bottom line.
- If your facility has a site EUI **close to the national median**, you are likely a good candidate for **adjustment**. Opportunities to make adjustments at your facility may involve a combination of major retrofit measures, less complex upgrades, and improved operations and maintenance practices.
- If your facility has a site EUI **significantly below the national median**, you should focus on **maintaining** your performance. In addition to maintaining your performance by focusing on ongoing building optimization, you should regularly assess major retrofit opportunities, particularly with respect to asset management.

The **questionnaire** is organized by:

Retrofit stage: Each column of questions represents a specific retrofit stage. Stages are presented from left to right in the order of the staged approach recommended in NRCan's *Major Energy Retrofit Guidelines: Principles Module.*

Site EUI: Within each column, measures have been labelled as Maintain, Adjust or Invest by the unique shape and colour of their checkboxes:

❑ **MAINTAIN**

❍ **ADJUST**

◇ **INVEST**

Facilities that are good candidates for investment should consider all measures; facilities are that good candidates for adjustment may choose to focus on Adjust and Maintain measures; facilities that want to maintain their performance may choose to focus primarily on Maintain measures.

PART 3

Instructions

1. Benchmark your facility using ENERGY STAR Portfolio Manager and determine your site EUI.
2. Assess the nature of the opportunities at your facility by answering the questionnaire with Yes, No or Not Applicable. The result should be a shortlist of relevant opportunities for your facility.
3. Consult the various sections of this module for more details on the relevant measures to confirm applicability. Once you have reviewed the details, you may find that some of the shortlisted opportunities should be labelled Not Applicable, or may not be of interest to your organization.

Measure costing

The return on investment for specific measures varies greatly based on many facility- and location-specific factors. You should always analyze costs and savings based on your specific situation. However, measures labeled:

❑ **MAINTAIN** are generally low-cost measures with payback periods under three years.

❍ **ADJUST** are generally low- or medium-cost measures with payback periods up to five years.

◇ **INVEST** are often higher-cost capital replacement measures. Payback periods for these measures typically exceed five years and in some cases may need to be justified with a renewal component (e.g. upgrade roof insulation when replacing a roof near the end of its life). These measures typically require detailed financial analysis to ensure a sound business case.

My Facility – Benchmarking Results

PORTFOLIO MANAGER INPUTS

Gross floor area: ______________________________

PORTFOLIO MANAGER OUTPUTS

Site EUI: ______________________________

Source EUI: ______________________________

Median property EUI: ______________________________

TARGETS

Site EUI target: ______________________________

Non-Food Retail – Opportunity Questionnaire

EBCx	Lighting upgrades	Supplemental load reduction	Air distribution systems upgrade	Heating and cooling resizing and replacement
❑ Do the lighting and occupancy schedules match? [Pg. 9] ❑ Is the air handling system on a schedule? [Pg. 9] ❑ Are the zone temperature set points being set back/forward during unoccupied hours? [Pg. 9] ❑ Does the RTU have a properly functioning economizer to enable free cooling? [Pg. 9] ❑ Have the BAS sensors been calibrated recently? [Pg. 10]	**Retail** ❍ Have frequently used incandescent fixtures been replaced with LED fixtures? [Pg. 17] ❍ Have incandescent Exit signs been replaced with LED signs? [Pg. 17] ❍ Have wall switches in enclosed rooms been replaced with occupancy/vacancy sensors? [Pg. 17] ◇ Has HID lighting been replaced with high-bay fluorescent lighting? [Pg. 18] ◇ Have daylight sources and lighting control been installed? [Pg. 18] ◇ Is lighting circuited for after-hours activities? [Pg. 18]	**Power loads and equipment** ❍ Is equipment being turned off when not in use? [Pg. 21] ❍ Have vending machine controls been added? [Pg. 21] ❍ Is ENERGY STAR equipment being used where applicable? [Pg. 21] ❍ Has an employee energy awareness program been implemented? [Pg. 22] ◇ Have transformers been replaced with energy-efficient models? [Pg. 22]	❍ Have high-induction swirl diffusers been installed in retail areas? [Pg. 33] ❍ Has heating been eliminated from front entrance vestibules? [Pg. 33] ◇ Is there a DCV system? [Pg. 34] ◇ Have destratification fans been installed in warehouses? [Pg. 34]	**Rooftop units** ◇ Has the CV system been converted to a variable flow system with demand control and an economizer? [Pg. 38] ◇ Has a compressor controller been installed on the RTU to reduce runtime? [Pg. 38] ◇ Has an economizer damper been added? [Pg. 39] ◇ Has heat or energy recovery been added? [Pg. 39] ◇ Has the old RTU been replaced with a new high-efficiency unit? [Pg. 39]

- ❑ Is the zone temperature deadband wide enough? [Pg. 10]
- ❑ Are the outside air dampers closed during morning warm-up during the heating season? [Pg. 10]
- ❑ Is an early morning flush performed regularly during the cooling season? [Pg. 10]

Warehouse

- ❍ Have incandescent Exit signs been replaced with LED signs? [Pg. 20]
- ◇ Has HID lighting been replaced with high-bay fluorescent or LED lighting? [Pg. 20]
- ◇ Have daylight sources and lighting control been installed? [Pg. 20]
- ◇ Have occupancy sensors been installed? [Pg. 20]

Exterior / parking lot

- ❍ Has exterior and parking lot lighting been replaced with LED lighting? [Pg. 20]
- ◇ Are photocell or timeclock controls being used? [Pg. 20]

Envelope

- ◇ Have infiltration issues been addressed? [Pg. 24]
- ◇ Has an air barrier been added or improved? [Pg. 25]
- ◇ Do roof and wall insulation levels meet NECB requirements? [Pg. 26]
- ◇ Have the windows and doors been upgraded? [Pg. 27]
- ◇ Have loading dock seals been added? [Pg. 28]
- ◇ Does the building have a "cool roof"? [Pg. 28]
- ◇ Have high-speed doors and/or air curtains been installed? [Pg. 28]

Warehouse heating

- ◇ Have infrared heaters been installed? [Pg. 40]
- ◇ Have direct-fired, blow-through heaters been installed in spaces with mechanical exhaust systems? [Pg. 40]

Domestic hot water

- ❍ Have low-flow aerators been installed? [Pg. 41]
- ◇ Has the hot water heater been replaced with a high-efficiency unit? [Pg. 41]
- ◇ Have storage-based hot water systems been replaced with tankless? [Pg. 41]