Natural Resources Canada
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Major Energy Retrofit Guidelines

for Commercial and Institutional Buildings

SUPERMARKETS

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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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DISCLAIMER

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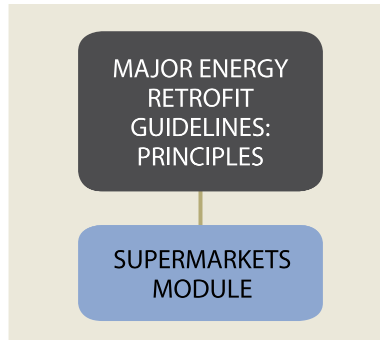
ENERGY RETROFIT OPPORTUNITIES IN SUPERMARKETS

PART 1

The Supermarkets 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 supermarkets.

The Supermarkets Module is divided into four parts:

1. **Retrofit Opportunities in Supermarkets:** Provides an overview of Canadian supermarkets. Subsections present background information on each retrofit stage and key retrofit measures.
2. **Case Study:** The case study showcases a successful major energy retrofit project.
3. **Business Case Guidance:** General information is provided on the costs and benefits for select retrofit measures based on example upgrade scenarios.
4. **My Facility:** This take-away section provides an Energy Efficiency Opportunity Questionnaire to assist you in identifying opportunities in your facility.



Supermarkets can be free standing, located in open air or strip centres, or in malls. The floor area includes all supporting functions, such as kitchens, break rooms for staff, refrigerated and non-refrigerated storage areas, administrative areas, stairwells, atriums, and lobbies.

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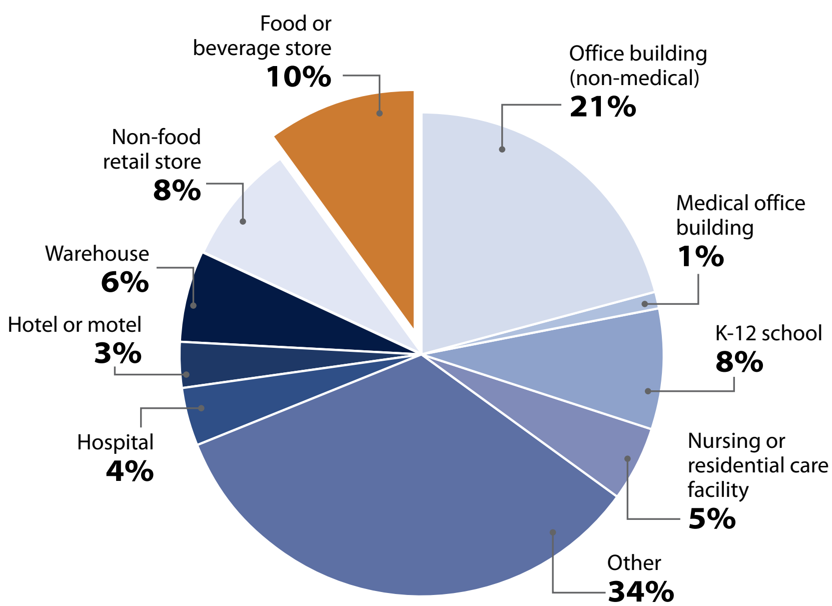
Supermarkets overview

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, food and beverage stores are the second largest energy-using subsector, accounting for 10% of energy use. This subsector is further delineated into two categories: supermarkets and food stores; the former being the focus of this module.

Supermarket business owners understand that they must create an inviting space for customers while also maintaining appropriate conditions for the grocery items being sold.[3] Luckily, there are many ways to improve the environment for customers and merchandise, while also addressing energy efficiency. For example, specific temperature and humidity control set points are required to maintain produce

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

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

3 ASHRAE. 2015. *Advanced Energy Design guide for Grocery Stores.*

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quality and appearance, while at the same time preventing condensation from forming on refrigerated case doors. As outlined later in this module, re-calibrating humidity controls and upgrading to desiccant dehumidification technology can improve conditions within your facility and save energy.

Supermarkets are high energy users, in part because of their large refrigeration loads, and addressing even marginal savings opportunities within these systems will have a noticeable impact on the overall energy consumption of the building. This module outlines numerous retrofit measures focused on improving the energy performance of display cases and walk-in coolers.

Another example unique to supermarkets is the heat that can be recovered from refrigeration compressor systems. These systems operate continuously to maintain proper food storage conditions in display cases and storage areas and, as a result, the heat rejected to the condensing circuits is significant. In many facilities, energy from this important but intensive process load can be captured and used to offset space or domestic water heating.

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.

Opportunities and challenges

The financial benefits of more energy-efficient buildings are widely known. 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. You may be experiencing increasing complaints from customers about cold temperatures in frozen food aisles or about the lack of prepared food sold at the store. Major capital equipment or building infrastructure, such as your refrigeration plant 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. Piecemeal additions or major internal space changes may also trigger a retrofit.

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).

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Opportunities

Energy savings are one of the principal benefits of a major retrofit project. As a result of the industry's narrow profit margins, $1 in energy savings is typically equivalent to increasing sales by over $50.[4] Lower energy consumption also limits your vulnerability to energy price fluctuations and reduces your greenhouse gas emissions.

In some cases, the net present value of the capital and operating costs for a new energy-efficient refrigeration system is less than the ongoing operating costs of an inefficient system. For example, installing refrigerated display cases with glass doors can significantly reduce both refrigeration compressor and condenser capacity requirements and lower space heating requirements.

Beyond energy savings, a notable benefit of major energy retrofits is often an improved corporate and community image. Supermarkets are an integral part of every community and can make changes to be better neighbours. For example, reducing exterior lighting and equipment operation when they aren't needed can reduce light and noise pollution, respectively.

Challenges

Major energy retrofits in supermarkets can face several challenges:

- Unique indoor environments: After labour costs,[5] energy expenses represent the most significant portion of the annual operating budget for most supermarkets. One of the reasons energy costs are typically so high is because supermarkets must carefully control temperature and humidity in order to create an inviting environment for customers, reduce product loss, and ensure that food safety requirements are met.
- Product changes: Merchandising trends are pushing supermarkets to become even more energy intensive than in the past; as stores carry more fresh food, frozen food aisles expand, and the demand for prepared food increases.
- Access to capital funding: Competition for funding poses a real challenge for supermarkets, 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.
- Incomplete asset management plans: Many independently-owned supermarkets 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 so that an energy efficiency strategy can be developed. For more information on asset management planning, see Section 2 of the Principles Module.

[4] United States Environmental Protection Agency. 2008. *ENERGY STAR® Building Upgrade Manual.*

[5] United States Environmental Protection Agency. 2008. *ENERGY STAR® Building Upgrade Manual.*

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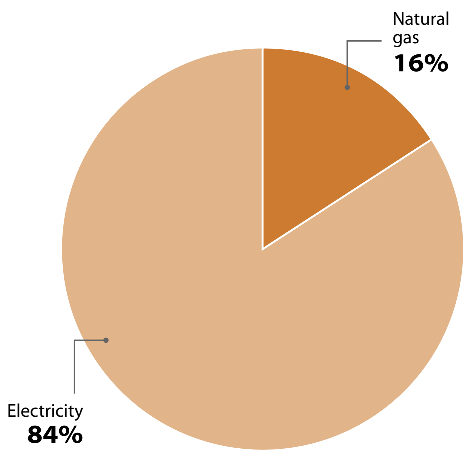
Energy use profile

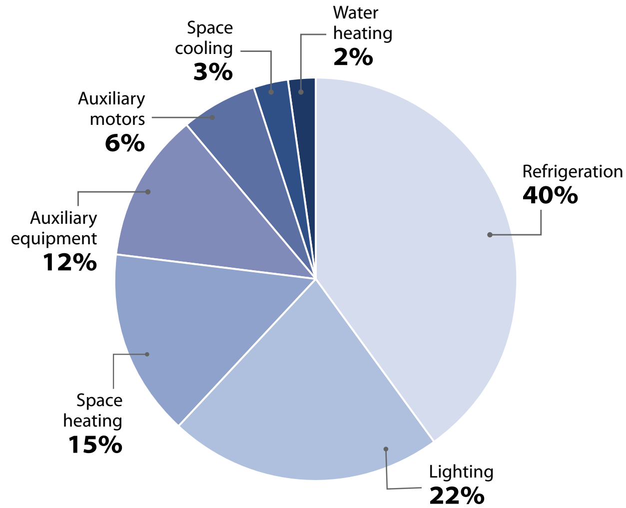
When planning your major retrofit project, consider the energy use profile for a typical Canadian supermarket. Although specific energy use profiles will vary depending on the type of services available on site, the example below can be used to provide a general indication of how you use your energy.

Figure 2. Energy use by energy source



Natural Resources Canada Existing Buildings Initiative (EBI) and ecoEnergy data

Figure 3. Energy use by end use



Natural Resources Canada EBI and ecoEnergy data

Figure 2 shows the breakdown of consumption by energy source. In this example, electricity provides more than 80% of the store's energy requirements. Figure 3 shows the breakdown of consumption by end use. Refrigeration is typically the largest end use, followed by lighting, space heating, and auxiliary equipment (e.g. food service equipment, other plug loads and computer equipment).

The national median site energy intensity for supermarkets in Canada is 3.1 GJ per square metre.[6] That is, half of Canadian supermarkets consume more than 3.1 GJ per square metre, while half use less. While the median site energy intensity can be a useful metric for comparison purposes, it should be noted that energy intensity in supermarkets can vary widely. This variation is influenced by weather conditions and specific facility and operating characteristics such as number of workers during the main shift, number of cash registers, number of computers, and length of refrigerated or frozen food display cases.[7]

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.

6 United States Environmental Protection Agency. 2014. *Canadian Energy Use Intensity by Property Type.*

7 United States Environmental Protection Agency. 2015. *ENERGY STAR® Score for Supermarkets and Food Stores in Canada.*

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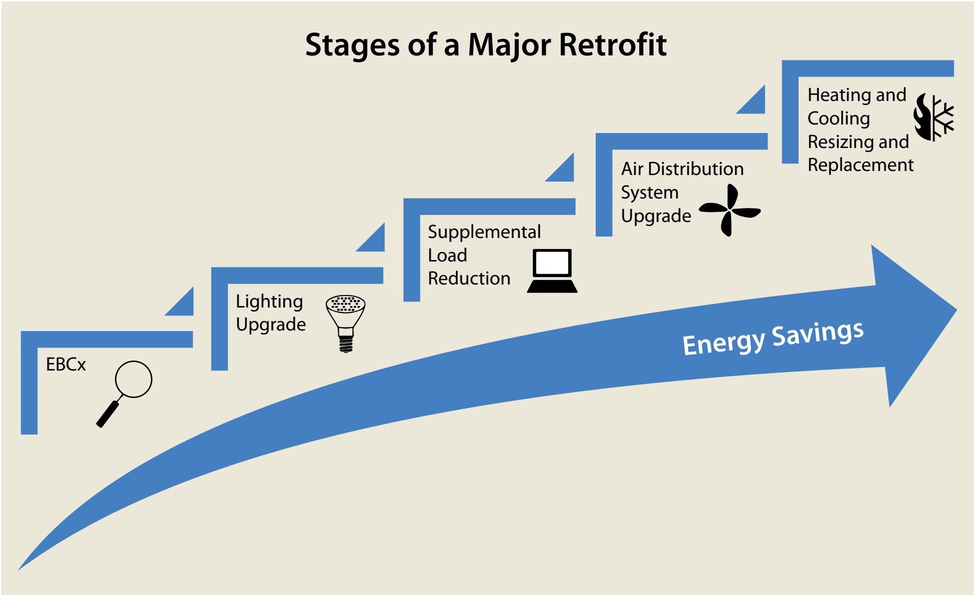
For many commercial and institutional building types, including food stores, ENERGY STAR Portfolio Manager provides an ENERGY STAR rating that scores energy performance on a scale of 1 to 100, relative to similar buildings.

An ENERGY STAR score provides a snapshot of your building's energy performance. It does not by itself explain why a building performs a certain way, or how to change the building's performance. It does, however, help you assess how your building is performing relative to its peers and identify which buildings in your portfolio offer the best opportunities for improvement.

Supermarket facility managers 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. 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.

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.



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

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.

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 of two years or less.[8]

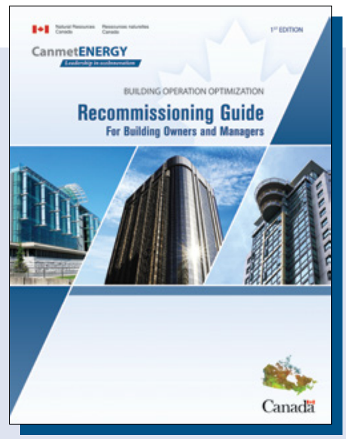
Savings from commissioning are achieved by improving building operations and restructuring maintenance procedures. Natural Resources Canada's (NRCan) *Recommissioning Guide for Building Owners and Managers*[9] shows you how to reduce operational expenses and increase revenue through improved building 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. They are based on the type of systems common to supermarkets, such as HVAC systems that are limited to single-zone constant volume rooftop heating and cooling units. It is important that all measures be implemented with suitable commissioning to ensure that system retrofits are optimized.[10]



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.

8 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.

9 Building Operation Optimization: Recommissioning Guide for Building Owners and Managers. http://www.nrcan.gc.ca/energy/efficiency/buildings/research/optimization/recommissioning/3795.

10 The Canadian Standards Association's Z320-11 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. http://shop.csa.ca/en/canada/building-systems/z320-11-/invt/27032582011.

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EBCx measure list
✓ Confirm lighting control schedule
✓ Schedule the air handling system
✓ Employ temperature setback during unoccupied hours
✓ Verify free cooling operation (air side)
✓ Reset supply air temperature
✓ Calibrate humidity control
✓ Check fan belts and pulleys for tension and wear
✓ Calibrate building automation system sensors
✓ Correct imbalances between supply air and exhaust
✓ Repair missing or damaged pipe insulation
✓ Seal ductwork to prevent leakage
✓ Investigate and correct refrigeration leaks
✓ Check and adjust case temperature controls
✓ Optimize defrost cycle
✓ Check heat recovery

- **Confirm lighting control schedule:** Confirm that the lighting control schedule matches the actual occupancy, and explore opportunities to reduce hours of lighting 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 the 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.

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- **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.[11]

  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.[12]

- **Reset supply air temperature:** Moderate weather, typically in spring and fall, permits a warmer supply air set point for cooling and a cooler supply air set point for heating. Energy savings are achieved as a result of the decreased heating and cooling demand.

- **Calibrate humidity control:** Refrigeration case manufacturers recommend that humidity levels in the store be limited to 55%. However, by lowering the relative humidity to 40%, defrost cycles are reduced, and space temperatures can rise to 24 °C without compromising the comfort of the occupants.[13] Furthermore, maintaining the relative humidity between 40 to 45% results in 10 to 15% savings in the display case operation.[14]

- **Check fan belts and pulleys for tension and wear:** Typical losses from belt-driven fans can be 2 to 6%.[15] These losses are due to belt tension, number of belts and the type of belts. Belt tension can be checked and corrected through a preventative maintenance program or by installing a self-adjusting motor base. Other losses from the belts and pulleys can be minimized through proper selection of these components as a "system" and by selecting grooved V-belts.

Case in Point:
Thrifty Foods

Thrifty Foods implemented a range of energy efficiency measures including installing new LED lights, reclaiming heat from hot water, adding direct digital controls to HVAC equipment, and installing more efficient refrigeration cases. Since 2010, the company has reduced energy consumption by 18%.

Source: BC Hydro, **https://www.bchydro.com/news/conservation/2013/thrifty-foods.html**

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[11] New Buildings Institute, Review of Recent Commercial Roof To Unit Field Studies in the Pacific Northwest and California, October 8, 2004. http://rtf.nwcouncil.org/NWPCC_SmallHVAC_Report(R3)Final.pdf.

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

[13] ASHRAE Handbook of Fundamentals shows that majority of the population is comfortable between 24 °C and 26.5 °C when RH is between 25 and 45%.

[14] Supermarket Application & Product Guide, Munters Corporation, www.munters.us.

[15] Stamper, Koral – Handbook of Air Conditioning, Heating and Ventilating.

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- **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.

- **Correct imbalances between supply air and exhaust:** Buildings should be neutrally or slightly positively pressurized compared to outside conditions. An air balancing should be conducted as part of the commissioning process to measure and assist in the corrective measures to restore proper balancing.

Figure 4. HVAC pipe insulation

- **Repair missing or damaged pipe insulation:** Routine inspections of heating and cooling pipe insulation can identify spots that require repair. Without insulation, energy is wasted in the form of standby losses and cycling losses (e.g. heat loss in unoccupied spaces as hot water cycles through pipes). HVAC pipe insulation for new buildings is listed in the NECB Table 5.2.5.3, and service hot water piping is listed in Table 6.2.3.1. The NECB can serve as a guide to determine possible insulation upgrades.

- **Seal ductwork to prevent leakage:** Properly sealed ductwork ensures that the intended design supply air is received at the diffuser and delivered to the occupant zone of the space. Leaky ductwork in supermarket environments wastes heating and cooling energy and requires more energy from the supply fan to deliver the required amount of conditioned air to the occupant zone. In these circumstances, the ventilation losses are returned to the air handling unit from the ceiling space.

- **Investigate and correct refrigeration leaks:** Supermarket refrigeration systems typically have a large refrigerant charge and can be prone to high leakage rates, a combination that can result in considerable refrigerant emissions. The U.S. Environmental Protection Agency (EPA) estimates that a centralized DX (direct expansion) system can emit as much as 25% of its refrigerant charge annually.[16] Leaks are caused by poor brazing of pipe joints, improperly tightened fittings, and missing valve caps and seals. Information on leak-tight refrigeration systems can be found in GreenChill's *Best Practices Guideline: Ensuring Leak-Tight Installations of Refrigeration Equipment*.[17]

It is good practice to regularly clean the surfaces of the evaporator and condenser coils as part of ongoing refrigeration system maintenance.

- **Check and adjust case temperature controls:** Unnecessarily low set points force compressors to work harder to maintain the cooler's temperature. Test and maintain an appropriate set point policy established for the type of refrigeration system and climate zone. Make sure you are working with an experienced energy management and refrigeration control expert to ensure that set points meet food safety regulations under all conditions.

[16] http://www.epa.gov/greenchill/downloads/EPASupermarketReport_PUBLIC_30Nov05.pdf.

[17] Available at http://www.epa.gov/greenchill/downloads/LeakGuidelines.pdf.

- **Optimize defrost cycle:** A significant amount of energy is required to defrost the evaporators in refrigerated display cases. Defrosting may be achieved by several methods:
  - Interruption of the flow of refrigerant to the evaporator
  - Electrical resistance heaters
  - Hot gas defrost (high temperature refrigerant vapour from the compressor discharge is routed through the evaporator)

  Defrosting also adds heat to the refrigerated display cases, which must be removed by the refrigeration system after termination of the defrost cycle. Not surprisingly, defrosting negatively impacts the shelf-life of food items and should be kept to a minimum.

  Most commonly controlled by a pre-set time schedule, defrost cycles typically occur every six or eight hours and are controlled to be temperature-terminated, with a fail-safe time backup. The temperature termination set point controls the length of the defrost cycle and, if set correctly, will result in energy savings. An ASHRAE-published report indicates that electric defrost heaters can account for up to 25% of the total electrical energy consumption of refrigerated display cases.[18]

- **Check heat recovery:** If applicable, verify operating conditions of heat exchangers on the refrigeration condensing circuit against design parameters to ensure optimized performance.

Lighting upgrades

Lighting consumes over 20% of the energy used in Canadian supermarkets 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 paybacks. Even simple upgrades can reduce lighting energy consumption between 10 and 85%[19] and have the potential to improve the customer experience. 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.

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.

[18] Mei, V.C., F.C. Chen, R.E. Domitrovic, and B.D. Braxton. "Warm liquid defrosting for supermarket refrigerated display cases." *ASHRAE Transactions* 108, no. 1 (2002): 669-672.

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

PART 1

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.

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 and provides a positive customer experience. Lighting designs need to address important elements such as luminance ratios, glare and colour qualities, in addition to the quantity of light. The NECB should also be consulted to ensure that maximum LPDs are not exceeded.

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. The efficacy and colour quality of LED light fixtures are advancing and quickly becoming the best option for replacement of incandescent, fluorescent and high intensity discharge lamps.
- 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.

Table 1. Illuminance Recommendations for Retail Facilities

Application and Task	Illuminance Targets (lux)[20]
General Retail	500[21]
Shipping and staging	300
Stock rooms	300

Lighting measures are discussed in the context of three typical supermarket environments: Retail, Stockroom and Staff Areas, and Exterior/Parking Lot lighting.

[20] Illuminating Engineering Society of North America (IESNA) recommended maintained horizontal illuminance levels measured at 76 cm above floor, where at least half of the observers are 25-65 years old.

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

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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

Food retailers use lighting not only to sell product, but also as a mechanism to create an atmosphere that reflect 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.
- 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 the 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 may require only four luminaires. Keep in mind that shiny surfaces will introduce more glare than matte finishes (light or dark coloured) and will also reflect light, while dark-coloured merchandise and containers will absorb light.

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

LPDs have decreased due to the 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, 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, 208 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.

High- and low-bay lighting technology

Retail buildings with open ceilings can be classified as high-bay for ceilings higher than 6.1 metres and low bay for ceilings less than 6.1 metres.

Figure 5. High-bay retail lighting

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High-bay lighting in retail environments has traditionally come in the form of high-intensity discharge (HID) metal halide (MH) fixtures, which typically have open reflectors. Low-bay fixtures may also be MH, but will be outfitted with diffusers. In recent years, standard HID lighting has been replaced by fluorescent or the new ceramic MH; most recently, high- and low-bay LED fixtures have also entered the market. There are a number of factors involved in the selection of light fixtures:

- 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). LED lamps, on the other hand, retain over 90% of their output at 60,000 hours.[22]
- 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 and lack of diffusers. There is little data available on fixture efficiency for LED-based luminaires, since many fixture designs have direct output LEDs without reflectors or diffusers. In many cases the fixture efficiency (efficacy) is the same as the efficacy of the LED array.
- On-off cycling: Lamp life is influenced by the number and duration of on-off cycles. Lamp life is increased by lowering the frequency and increasing the duration of on-off cycles (i.e. turning the lights on and off fewer times over the course of the day). This is not a factor for LED technology.
- Colour: Colour rendering index (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 can exceed 90, making it a good choice when colour accuracy is important. As noted previously, the LED industry is rapidly evolving, and more options for high CRI are being developed.
- 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 3 minutes. Similarly, fluorescent lamps will restrike (switching back on after being turned pff) 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. LED lamps are instant-on and do not have a warm-up period.

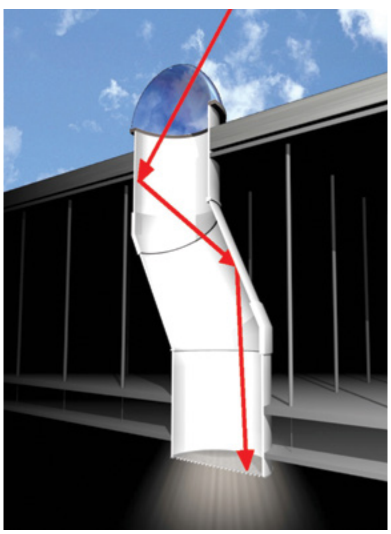
[22] IESNA TM-21-11, diode junction temperature 55 °C.

PART 1

Figure 6. Sealed dome skylight

Source: Wikimedia Commons (User: Masur)

Figure 7. Light tube skylight



Source: Peter Ellis, Richard Strand, Kurt Baumgartner. Simulation of Tubular Daylighting Devices and Daylighting Shelves in Energy Plus. BuildSim 2004.

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 electrical 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 or poor lighting for merchandise. 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. Lighting controls that respond to daylight levels through dimming or switching should adjust electrical lighting levels gradually to ensure that merchandise continues to be displayed properly and to provide a better environment for occupants.

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, **T5-HO fixtures 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

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 outputs. 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.

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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%.[23]

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.

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:
Wal-Mart Daylighting Strategy

Since 1995, Wal-Mart has been capturing natural light in its stores through skylights equipped with dimming systems. As light increases during the day, interior lights are automatically dimmed or shut off entirely. More than 2,000 Wal-Mart stores worldwide use the system, with annual savings of about 250 MWh, or about 25% less than similar big-box competitors. With the skylights installed, light levels average just over 1,076 lux (100 foot-candles) throughout the building.

Source: Sunoptics, **http://www.sunoptics.com/success_stories/retail/walmart/wal-mart.aspx**.

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

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To test the impact of lighting retrofits, it can be useful to apply them to one floor or to a designated area to gauge the impact on occupant comfort, before extending the retrofits to similar spaces.

Lighting measure list (retail)
✓ Replace high-intensity discharge lighting with high-bay fluorescent or LED fixtures
✓ Replace incandescent and fluorescent lamps with LED lamps
✓ Replace incandescent Exit signs with LED signs
✓ Install daylight sources and lighting control
✓ Circuit lighting for after-hours activities

- **Replace high-intensity discharge lighting with high-bay fluorescent or LED fixtures:** Replacing quartz MH lighting with T5-HO offers 23% energy and power savings. See the **Business Case Guidance** section for information on the costs and benefits of an example upgrade scenario.

- **Replace incandescent and fluorescent lamps with LED lamps:** MR16 incandescent lamps are commonly used in pendant and recessed fixtures. Savings of almost 80% are available by directly replacing a 50-W MR16 lamp with an 11-W LED with a CRI of 92. See the **Business Case Guidance** section for information on the costs and benefits of an example upgrade scenario.

- **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. LED exit signs consume approximately 1 W of energy compared to an 11-W compact fluorescent, a savings of 90%. See the **Business Case Guidance** section for information on the costs and benefits of an example upgrade scenario.

- **Install daylight sources and lighting control:** A well-designed daylighting strategy with photosensor lighting controls that dim or 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.

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Stockroom and staff areas

Lighting in stockrooms, loading docks and receiving areas must provide sufficient illumination for worker visibility, safety and performance.

Figure 8. Stockroom lighting

The light levels and visibility required in a stockroom 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 more illumination than areas with larger items and larger text.

Stockrooms can have both vertical and horizontal stack surfaces. Adequate levels of vertical illumination are essential for workers to read labels and signs within the facility (including Exit signs), and to drive a forklift.

In stockrooms, staff must also 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.

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.

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High-bay Lighting Technology

The most efficient lighting sources suitable for stockroom spaces include high-bay 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 Stockrooms

Stockroom 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-type spaces and, with correct design, can save energy.

Lighting measure list (stockroom & staff areas)
✓ Replace incandescent and fluorescent lamps with LED lamps
✓ Replace incandescent Exit signs with LED signs
✓ Replace stockroom high-intensity discharge lighting with high-bay fluorescent or LED fixtures
✓ Install daylight sources and lighting control
✓ Install occupancy sensors in stockroom areas
✓ Replace wall switches in enclosed rooms with occupancy/vacancy sensors

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- **Replace incandescent and fluorescent lamps with LED lamps:** MR16 incandescent lamps are commonly used in pendant and recessed fixtures. Savings of almost 80% are available by directly replacing a 50-W MR16 lamp with an 11-W LED with a 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 stockroom 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%.[24]
- **Install daylight sources and lighting control:** A well-designed daylighting strategy with photosensor lighting controls that dim or switch off fixtures when adequate daylight is available can save significant energy as well as maintenance costs.
- **Install occupancy sensors in stockroom areas:** Stockroom areas can be outfitted with occupancy sensors and multi-level lighting control.
- **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 the 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. EPA estimates savings potential under optimal conditions ranging from 25 to 75% of lighting energy, depending on space type.[25]

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

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

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Exterior or parking lot lighting

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 has been well suited for exterior lighting applications for a number of years.

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.

Figure 9. LED parking lot lighting

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. See the Business Case Guidance section for information on the costs and benefits of an example upgrade scenario.
- **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 the 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. See the Business Case Guidance section for information on the costs and benefits of an example upgrade scenario.

PART 1

Supplemental load reduction

Supplemental load sources are secondary load contributors to energy consumption in buildings (occupants, computers and equipment, the building envelope 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 supermarket environment, as well as electrical distribution transformers.

Supplemental load measure list (power loads & standard equipment)
✓ Power off equipment when not in use
✓ 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.

- **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. Instituting an effective policy can be as easy as asking procurement staff to specify ENERGY STAR-certified products such as computers, office equipment, lighting fixtures and lamps, kitchen equipment and electronics. The textbox below provides further information on commercial kitchen equipment.

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

Commercial kitchen equipment

A wide range of equipment, fixtures and appliances contribute to energy consumption in supermarket kitchens, which means that there is also a wide range of possibilities for reducing energy.

Only 35% of the energy consumed in a typical commercial kitchen is used for cooking and food preparation; the rest is wasted within the room as heat. By using more energy-efficient equipment, not only is energy consumption reduced, but comfort and air quality are improved. Replacing existing equipment with new high-efficiency alternatives can save up to 70% of energy use.

Table 2 highlights typical savings for various kitchen equipment and indicates whether ENERGY STAR-certified products are available:

Table 2. ENERGY STAR-certified products

Category	Equipment	Typical energy savings	Typical water savings	ENERGY STAR-certified
Refrigeration	Commercial refrigerators and freezers	35%	–	Yes
	Commercial ice machines	15%	10%	Yes
Sanitation	Commercial dishwashers	25%	25%	Yes
	Pre-rinse spray valves	Varies	55 to 65%	No
	Water heaters	5%	–	Yes
Food preparation	Commercial fryers	30 to 35%	–	Yes
	Commercial griddles	10%	–	Yes
	Commercial hot food holding cabinets	65%	–	Yes
	Commercial ovens	20%	–	Yes
	Commercial steamers	50%	90%	Yes

Source: NRCan. 2012. *ENERGY STAR Guide for Commercial Kitchens*

Kitchen ventilation also has a significant impact on energy consumption. Energy demand can drop considerably if kitchen appliances are the right size, if heat is recovered from exhaust air, and if the ventilation system has a demand control system. Some kitchen appliances even have integrated solutions that reduce the need for exhaust air. Refer to the Air distribution systems upgrade stage for more information.

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- **Implement an employee energy awareness program:** NRCan's Implementing an *Energy Efficiency Awareness Program*[26] can help owners and managers develop successful employee energy awareness programs. Another useful resource is the ENERGY STAR Guidelines for Energy Management.[27] 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.

  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.

  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.[28]

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 heat 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 10 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

[26] http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/Publications/commercial/pdf/Awareness_Program_e.pdf.

[27] http://www.energystar.gov/buildings/about-us/how-can-we-help-you/build-energy-program/guidelines.

[28] HPS Energy Savings Calculator, http://www.hpstoolbox.com/.

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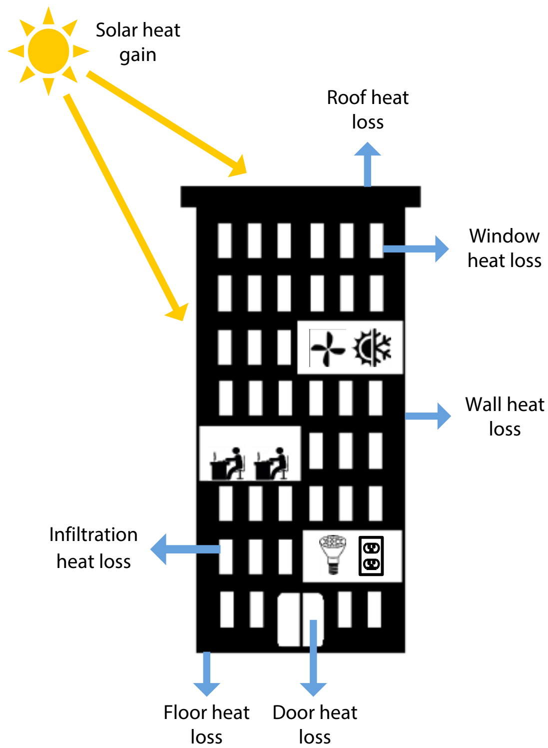
Figure 10. Building envelope heat transfer



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 the 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.).

See the **Business Case Guidance** section for information on the costs and benefits of three example upgrade scenarios.

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

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- **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. The energy impacts of unintended infiltration on building energy use have been shown to be significant. As HVAC equipment and other building systems continue to become more efficient, the energy loss associated with building envelope leakage is representing an even greater percentage of total building energy consumption.

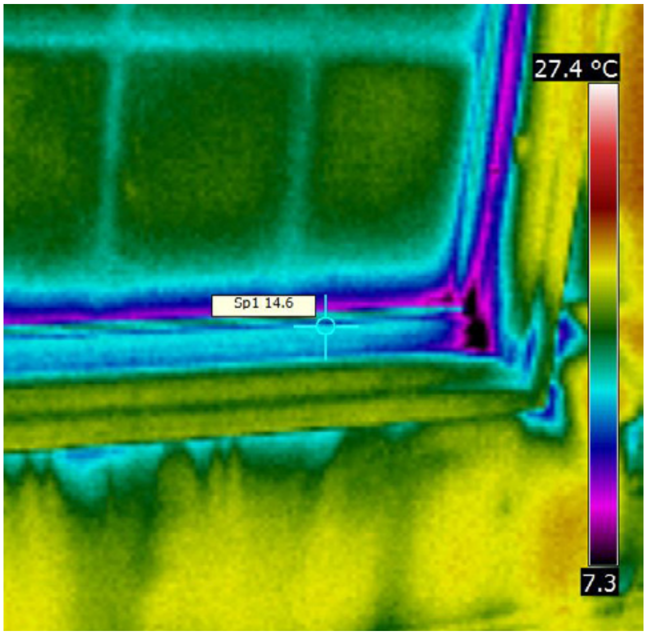
  Infiltration can also be exacerbated by a positively or negatively pressurized building. The effects of building pressurization will be experienced when a door is opened: a distinct flow of air will be felt either entering or leaving the building. Building pressure should be neutral or very slightly 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 11 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).

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 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.

Figure 11. Infrared imagery showing leakage around 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 for this investigative tool to be effective.

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, stack effect and pressure differentials caused by mechanically introducing or removing air 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%.[29]

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

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- **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 disruption to 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.

- **Upgrade windows and doors:**

  Windows

  Windows have an impact on a building's operating costs and on the 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.

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 effective wall and roof RSI-values for climate zones 5, 6 and 7:

Zone 5
(e.g. Kelowna, 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)

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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.[30]

The text box on page 32 provides a more detailed discussion of each of these criteria, along with a discussion of various window components and assemblies.

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.

- **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: **www.coolroofs.org**.

[30] 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}.

PART 1

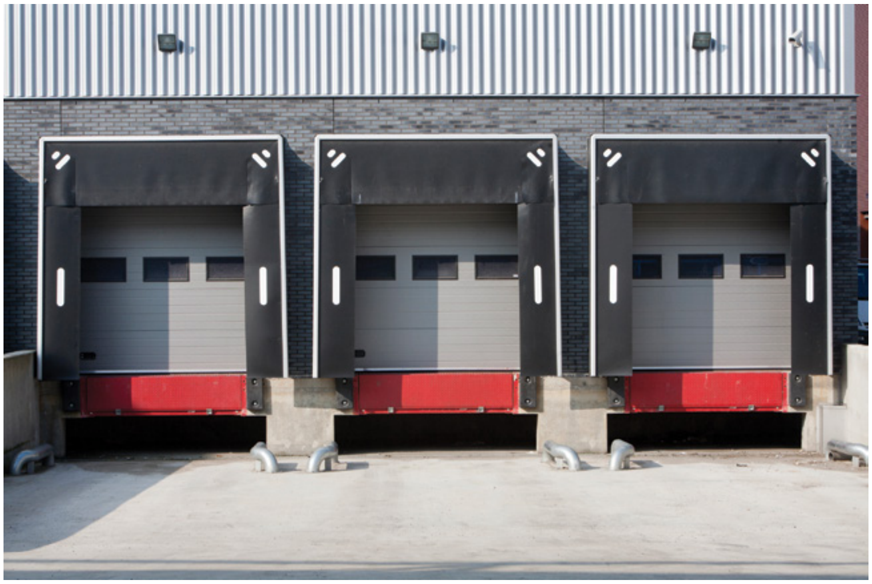
- **Install high-speed doors and air curtains:** High-speed doors and air curtains[31] provide climate control for entranceways, stockroom areas, or large storage freezers that are frequently accessed. Such devices can also provide additional isolation for the loading dock area.

- **Upgrade loading dock doors and install loading dock seals:** Roll-up loading dock doors can be a source of significant heat loss due to poor thermal properties of the doors, infiltration and operational practices. In recent years, loading dock doors have been greatly improved, and it is recommended that the condition of existing doors be examined to determine if a replacement would correct poor performance issues.

  There is an even stronger business case to consider dock seals and dock shelters because they provide an environmental barrier that significantly reduces infiltration. Dock seals and shelters can be easily retrofitted to the outside of the building to save energy.

Figure 12. High-speed door

Figure 13. Loading dock seals



- **Add a vestibule:** The NECB 2011 prescriptive path requires that new buildings 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.

[31] http://e3tnw.org/ItemDetail.aspx?id=427.

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.

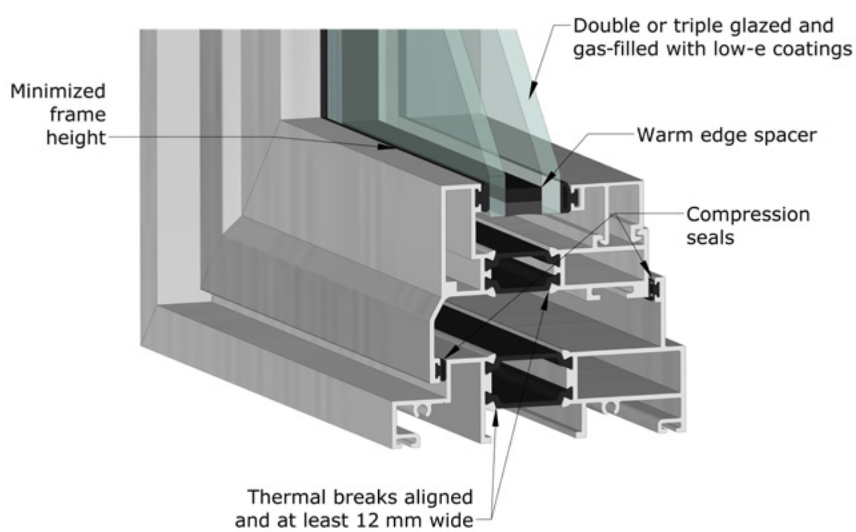
IGU performance is determined by:

- 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 14. 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

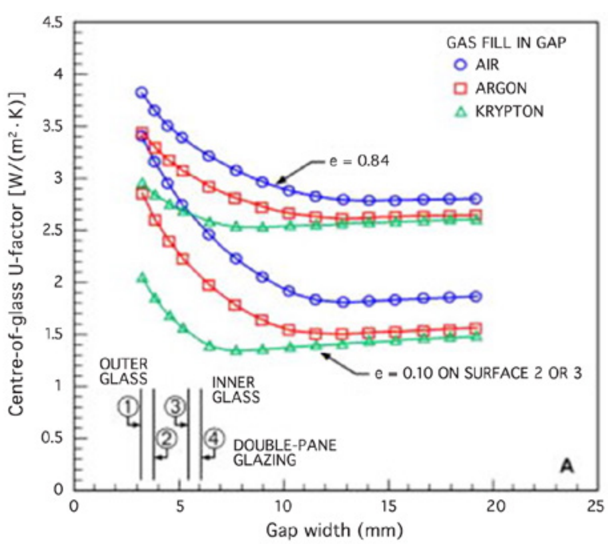
A window's U-factor incorporates the thermal properties of both the frame and the glazing. Since the sash and frame represent approximately 10 to 30% of the total area of the window unit, the frame's properties significantly influence the total window performance.

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 15 plots the relative performance of air, argon and krypton gas fills.

Figure 15. 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 system 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.

Supermarket environments are unique among commercial buildings with respect to challenging temperature and humidity control dynamics. Factors may include:

- Produce that needs to be stored within specific relative humidity limits
- Open refrigerated cases that spill cold air into the retail area
- Produce being sprayed with water mist that introduces additional humidity
- Cooking equipment that requires large volumes of exhaust

The key to overcoming these challenges is to analyze sensible and latent loads independently. Supermarkets have extremely high latent loads compared to their sensible loads and therefore require dedicated humidity control. Condensation forming on refrigerated case doors is a symptom of high humidity levels, a very undesirable condition. The humidity control calibration measure under the EBCx stage suggests that relative humidity should be maintained within the range of 40 to 45%.

In addition to dedicated dehumidification equipment, rooftop units (RTUs) are the main type of system used to distribute and condition air in supermarkets. The lowest cost option to reduce RTU energy is to expand the allowable ranges for indoor temperatures, i.e. allowing temperature 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 in concert with the required humidification set points, you can determine the acceptable range for temperature and humidity. These comfort ranges can be found in ASHRAE Standard 55.[32]

ASHRAE Standard 55 comfort range example

Acceptable temperature and humidity ranges depend on activity levels and clothing. Hotel 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 are assumed).

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

Sensible heat transfer is related to changes in air temperature.

Latent heat is the energy absorbed or released during a phase change from a gas to a liquid or vice versa.

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

It is important to note that areas that have open refrigeration cases will experience localized over-cooling and possible discomfort for the occupants. To address this issue, it is recommended that doors be installed on open cases. Refer to **Refrigeration Systems** for more information.

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,[33] 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.

Air distribution systems measure list
✓ Start with first-order measures
✓ Use demand control ventilation
✓ Install air turbines for destratification in retail area
✓ Install high-induction swirl diffusers in retail area
✓ Install high-volume, low-speed fans in stockrooms
✓ Eliminate heating in front entrance vestibule
✓ Replace direct expansion dehumidification with desiccant

- **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 RTU. 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.

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

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- **Use demand control ventilation (DCV):** DCV ensures that a building is adequately ventilated while minimizing outdoor air flows. Supermarkets typically have a great deal of variation in occupancy levels, making them ideal candidates for DCV. With DCV, 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.)

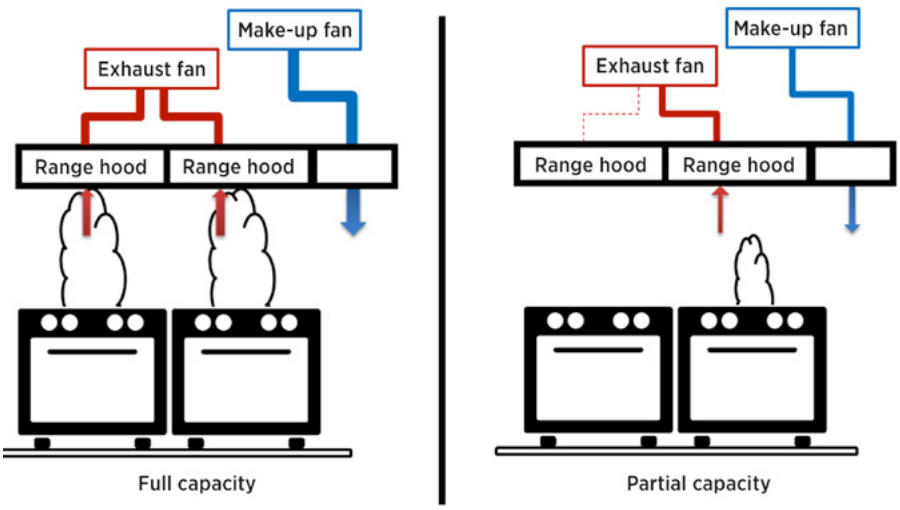
Kitchen hood exhaust

DCV can also be applied in supermarket kitchens; however, instead of controlling ventilation using CO_2 sensors, hood exhaust fans are controlled in response to temperature, optical or infrared sensors that monitor cooking activity, or direct communication with cooking appliances.

Food preparation equipment and kitchen ventilation can be large energy consumers in supermarket kitchens. Exhaust hood air flow is the most significant source of this energy consumption. The first step in reducing energy is to reduce exhaust air flow by using high-efficiency hoods with low capture and containment air flow rates. The second step is using DCV to further reduce exhaust air flow when cooking is not taking place under the hood, as shown in Figure 16.

With a kitchen DCV system, the hood operates at full design air flows whenever cooking activity is at full capacity, but is reduced when reduced load cooking is taking place. The system controls both the make-up fan and hood exhaust fan to ensure balance in the ventilation system. Such systems can save 60% or more on kitchen ventilation energy.[34]

Figure 16. Demand control kitchen ventilation



[34] http://www.energystar.gov/about/2014-2015-emerging-technology-award-demand-control-kitchen-ventilation.

Historically, building ventilation systems were designed to operate at constant or pre-determined ventilation rates, regardless of occupancy levels. Since ventilation rates are normally based on maximum occupancy levels, running fans and conditioning the excess outdoor air wastes energy during periods of only partial occupancy. Economizer controls should always override DCV in control sequences.

- **Install air turbines for destratification in retail area:** Air turbine destratification fans feature a venturi nozzle that delivers effective circulation to maintain a consistent air temperature from ceiling to floor.

- **Install high-induction swirl diffusers in retail area:** Displacement ventilation is a method of delivering fresh air to occupants near the floor of the 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.

- **High-volume, low-speed fans in stockrooms:** High-volume, low-speed (HVLS) fans are considered air movement systems, not just cooling systems. They move and mix large volumes of air and are very effective in helping with cooling, heating (through heat destratification) and ventilation.

  HVLS fan blades 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.

  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.

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 supermarket 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

- **Eliminate heating in front entrance vestibule:** Many supermarkets 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.

  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.[35]

- **Replace direct expansion dehumidification with desiccant:** Conventional direct expansion (DX) systems are not an efficient option to manage latent loads, since they must first overcool the air (to dehumidify) and then reheat it to maintain store comfort. Using desiccant technology to dehumidify allows humidity to be controlled independently of temperature and therefore uses less energy than DX.

Heating and cooling resizing and replacement

This section covers the main heating and cooling system types, including supermarket refrigeration systems, RTUs, as well as domestic hot water systems. RTUs are the main space conditioning systems in supermarkets, with the exception of their stockrooms, which have some additional heating options.

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.

Refrigeration systems

Refrigeration systems are by far the largest end use, consuming approximately 40% of a supermarket's total energy. Addressing even marginal savings opportunities within these systems will result in a noticeable impact on the building's overall consumption. Refrigeration systems are critical for food safety and must be evaluated by refrigeration professionals to ensure that proper system temperatures are delivered across all conditions.

NRCan's **CoolSolution®** approach brings together leading-edge refrigeration technologies and practices to lower energy consumption and reduce the carbon footprint of supermarkets along three axes:

- Heat recovery
- Energy efficiency of refrigeration systems
- Reduction of synthetic refrigerant charge

For more information about the CoolSolution® approach, visit: **http://www.nrcan.gc.ca/energy/efficiency/buildings/research/refrigeration/3843**

35 http://e3tnw.org/ItemDetail.aspx?id=427.

PART 1

Unlike other retail environments, where temperature control is the sole focus, supermarkets require an emphasis on humidification control. Extensive research in the area of supermarket indoor environmental conditions recommends that relative humidity be maintained between 40 and 45%. This range maintains good product appearance and quality, reduces frost, keeps case glass surfaces clear, and saves energy.

The measures below are broken into measures for display cases, walk-in coolers and freezers, and the compressor-condensing circuit. See the Business Case Guidance section for information on the costs and benefits of three example upgrade scenarios.

Display Cases

Heating & cooling measure list (refrigeration systems: display cases)
✓ Use case doors with zero heat on medium-temperature cases
✓ Use night curtains on medium-temperature cases during unoccupied hours
✓ Control anti-sweat heaters to cycle based on dew point
✓ Use demand defrost control
✓ Centralize compressors and locate them away from retail area
✓ Use LED lamps
✓ Install electronically commutated motors on evaporator fan motors

- **Use case doors with zero heat on medium-temperature cases:** Closed display cases have become the norm in new supermarket design, and many companies offer retrofits for existing equipment. Retrofitting open refrigerated display cases with transparent doors reduces refrigeration energy, increases the potential savings from building HVAC energy and increases shopper comfort levels. Case studies have shown an average of 30% savings from the application of doors on display cases.[37] Many studies have also shown that closed display cases do not negatively affect sales.

  Furthermore, the application of heat around door seals, historically used to eliminate condensation on the door frames and glass, is not required for medium-temperature coolers if humidity is properly controlled within the building.

Using CO_2 Instead of Synthetic Refrigerant

CO_2 is a natural refrigerant (R-744) that is becoming the refrigerant of choice for grocery store chains. Compared to traditional refrigerant systems, CO_2 has a lower global warming potential and delivers better temperature control, allowing for more consistent quality of the refrigerated products. According to Canadian Grocer,[36] CO_2 refrigeration systems cost less to install than traditional systems, and have lower ongoing energy and maintenance costs.

[36] http://www.canadiangrocer.com/uncategorized/at-supermarkets-natural-refrigeration-reaches-toward-a-tipping-point-31534

[37] http://greeningretail.ca/best/energy-conservation/best_energy_conserv_refrig.d.

Automatic Sensors

In their Nova Scotia stores, Sobeys installed automatic sensors on the heaters for the glassed-in coolers.

"When the humidity and heat is such inside the building that you have issues with condensation, the doors have heaters on them," said Keith Ross, senior manager of maintenance and sustainability, Sobeys Atlantic. "But at certain times of the year, you don't need them. They go on and off automatically now."

Source: Canadian Grocer, http://www.canadiangrocer.com/uncategorized/at-sobeys-in-nova-scotia-lights-motors-and-going-green-22371.

Figure 17. Supermarket display cases

- **Use night curtains on medium-temperature cases during unoccupied hours:** Night curtains are a relatively simple measure to reduce the energy use of open refrigerators and freezers. Easily put in place at night and removed in the morning, night curtains are reflective and secured by a magnet at the bottom of the case. Payback has been calculated at three years for this initiative.[38]
- **Control anti-sweat heaters to cycle based on dew point:** Most anti-sweat door heaters typically run at full power, continuously, all year long. While this does a good job of keeping the doors clear and dry, it consumes more energy than necessary, especially when conditions in the store do not require full heat output. By monitoring the store's dew point, controls can cycle the heaters to supply just enough heat to keep frames and glass condensate free. Savings of up to 50% can be achieved on low-temperature (freezer) doors.
- **Use demand defrost control:** Although timing-initiated, temperature-termination controls with a failsafe time backup are the most common strategy, this control method is not based on the actual amount of frost on the evaporator. For example, if the defrost cycle is insufficient to remove all the ice, this can result in longer run-times for the refrigeration system compressors due to suboptimal performance of the evaporator. Alternatively, if the defrost cycle runs too long, it wastes energy. Other alternatives are available that provide a "demand control" for defrost cycles.[39] Examples include methods that end the defrost cycle based on evaporator pressure, time cycles based on relative humidity inside the display case, and measure frost accumulation with optical sensors.

[38] Ibid.

[39] http://info.ornl.gov/sites/publications/files/pub31296.pdf.

PART 1

- **Centralize compressors and locate them away from retail area:** Many display cases are manufactured with integral compressors. The result is a noisy environment near the case and a lost opportunity for high-efficiency condensing operation (see Compressor Systems, page 45). To eliminate the noise and cooling inefficiency, the equipment should be retrofitted with remote compressors and integrated with the store's central refrigeration system.
- **Use LED lamps:** LED lighting saves energy, enhances brightness and provides more uniform illumination. LEDs also work well in the cold and last over 50,000 hours in a cooler and 100,000 hours in a freezer.[40] For comparative purposes, a 1.2-m fluorescent fixture consumes 32 W, while the equivalent LED consumes 15 W, a 52% saving.
- **Install electronically commutated motors on evaporator fan motors:** Evaporator fans typically run continuously to circulate air inside refrigerated spaces. An electronically commutated motor (ECM) is a brushless, permanent magnet direct current motor that is able to operate at high efficiencies over a wide range of speeds. Full-load efficiency of an ECM exceeds 70% (85% in some cases), compared to the 25 to 50% full-load efficiency of standard motors. For example, a 44-W ECM can replace a 135-W standard 1/8 horsepower motor, yielding a 67% power savings.

Walk-in coolers and freezers

Heating & cooling measure list (refrigeration systems: walk-in coolers and freezers)
✓ Upgrade insulation
✓ Use fan control to turn fans off while doors are open
✓ Use two-speed evaporator fans
✓ Install electronically commutated motors on evaporator fans
✓ Use advanced electric defrost for low-temperature freezers
✓ Use free cooling
✓ Install strip curtains
✓ Turn cooling off while doors are open
✓ Add door closures
✓ Use air defrost for medium-temperature coolers
✓ Use LED lamps

LEDs save electricity and reduce heat

Thrifty Foods (BC) replaced its display case lighting with LED lighting.

"When you upgrade refrigeration cases with LEDs, you save twice as much energy," said Jerry Wyshnowsky, energy manager, Thrifty Foods. "With the old cases, you're paying more to run the lights and, on top of that, they're heating the case so you have to use more energy to get that heat out. With LEDs, the lighting uses less energy, and you're not introducing heat into the case."

Source: BC Hydro, https://www.bchydro.com/news/conservation/013/thrifty-foods.html.

[40] http://blog.uscooler.com/retrofit-led-lights-c-store/.

PART 1

Figure 18. Walk-in cooler

- **Upgrade insulation:** Walk-in coolers should be insulated to a minimum of RSI 3.5 (R-20) ; freezers to RSI 5.0 (R-28). Insulation should be impervious to moisture, such as closed cell styrene or foil-faced urethane panels. Review the manufacturer's specifications for your walk-ins and determine if a retrofit option is available where existing insulation does not meet these minimum values.
- **Use fan control to turn fans off while doors are open:** Evaporator fans circulate air inside refrigerated spaces to keep temperatures consistent. Circulating air during periods when doors are open for restocking or retrieving stock is unnecessary and can potentially accelerate cooled air exiting the walk-in. Door switches can be added to turn fans off when doors are open.
- **Use two-speed evaporator fans:** Two-speed motors can be used to reduce power consumption and thermal losses by switching fans to low speed (e.g. reducing speed by 80%) when compressors are off (i.e. when no heat is being extracted from the walk-in). On low speed, the required circulation for destratification is still accomplished while saving on fan energy. Since fan power is proportional to the fan speed cubed, reducing the fan speed reduces energy consumption significantly.
- **Install electronically commutated motors on evaporator fans:** Installing ECMs on evaporator fans, as outlined in the context of display cases, is equally effective for walk-ins.
- **Use advanced electric defrost control for low-temperature freezers:** Standard electric defrost cycles are controlled with a timeclock to start and stop the defrost cycle regardless of whether or not the evaporator coil actually requires defrosting. Starting the defrost cycle at regular timed intervals is important to maintain frost-free coils; however, the time to achieve the required defrosting varies according to conditions within the walk-in. To achieve the appropriate amount of defrosting, controls can be added to terminate the defrost cycle based on pressure or temperature.
- **Use free cooling:** Free cooling is a viable option for walk-in refrigerated spaces. A free cooling system delivers cold outdoor air into the refrigerated space when outdoor temperatures are suitable. The direct use of cold outdoor air can save considerable compressor and evaporator fan runtimes in many locations in Canada. For example, in Montreal, the outdoor temperature is below 4 °C for 3,563 hours per year. A number of companies have engineered retrofit systems for these applications.

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- **Install strip curtains:** Strip curtains are used to reduce the cooling load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers and freezers. Engineering studies show that walk-in doors can typically be open between two and two and a half hours per day. According to various studies conducted in the U.S., the average energy savings associated with strip curtains can range from 420 kWh/door/year for coolers and around 2,900 kWh/door/year for freezers.[41]
- **Turn cooling off while doors are open:** When walk-in freezers and coolers are open, the load increases on the refrigeration system to overcome the warmer air entering the space. Forcing the system to work against this additional load is a waste of energy, since open doors will continue to allow warm air into walk-ins, while the cold air exits. Simple compressor controls that recognize when doors are open can eliminate this wasted energy.
- **Add door closures:** To eliminate accidental open doors and the resulting additional cooling load, door closures can be added.
- **Use air defrost for medium-temperature coolers:** Air defrost uses the evaporator fan to clear ice from the coil during periods when the compressor is off. Medium-temperature coolers are typically set to 4 °C, which is a suitable temperature for defrosting. Air defrost is the lowest energy option for medium temperatures, compared to hot gas or electric defrost, because it uses the existing conditions within the cooler.
- **Use LED lamps:** LED lighting saves energy and adds minimal heat to the space. LEDs also work well in the cold and last over 50,000 hours in a cooler and 100,000 hours in a freezer.[42] For comparative purposes, a 1.2-m fluorescent fixture consumes 32 W, while the equivalent LED consumes 15 W, a 52% savings.

Compressor systems

Heating & cooling measure list (refrigeration systems: compressor systems)
✓ Recover heat from condensing circuit
✓ Use hybrid condensers and pre-cooling
✓ Reduce floating head pressure and floating suction pressure
✓ Use electronic expansion valves
✓ Install variable speed fans on low-temperature condensers
✓ Add ambient refrigeration subcooling to condenser circuit
✓ Install digital compressors and controls

[41] www.oesolutions.net.

[42] http://blog.uscooler.com/retrofit-led-lights-c-store/.

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Case in Point:
Thrifty Foods (BC)

Thrifty Foods transfers heat from its refrigeration systems to heat water and warm other areas of the store. On colder days, they sometimes need a little boost, but otherwise the recovered heat (cast off by the cooling systems) supplies most of the water and space heat required by the stores.

Source: Thrifty Foods, http://www.thriftyfoods.com/EN/minor/about/sustainability/green-aisle/green-buildings.html and BC Hydro, https://www.bchydro.com/news/conservation/2013/thrifty-foods.html.

Figure 19. Refrigeration compressor

- **Recover heat from condensing circuit:** Refrigeration systems operate continuously to maintain proper food storage conditions in display cases and storage areas. As a result, the heat rejected to the condensing circuit is significant. Since this heat is considered to be low quality, based on the low temperatures, the recovery of this heat is only suitable for space or water heating.

- **Use hybrid condensers and pre-cooling:** Hybrid condensers present an attractive option where there are peak electricity rates and high summer demand. They consist of an air-cooled condenser and use evaporative cooling during peak cooling (high ambient) conditions. Evaporative cooling lowers the peak saturated condensing temperature and compressor power compared to air-cooled condensers. Outside of peak conditions, the standard air-cooled condenser eliminates water use and potentially lowers head pressure, compared to an evaporative condenser.

  An evaporative pre-cooling system can be added to standard air-cooled condensers to take advantage of the more efficient cooling during peak conditions. Control strategies must optimize the saturation efficiency and other balancing objectives to overcome the additional pressure drop on fan power and/or condenser air flow. To evaluate the cost effectiveness of a hybrid system, hourly year-round performance must be considered.

- **Reduce floating head pressure and floating suction pressure:** Refrigeration systems typically have fixed high- and low-pressure set points that determine when the compressors start and stop. These set points are often determined by the cooling requirements of hot, humid summers, but are rarely adjusted to allow refrigeration systems to take advantage of lower ambient temperatures throughout the rest of the year. By reducing the head pressure based on the condenser's capacity to provide free cooling, overall system energy consumption can be significantly reduced. Given that some Canadian climate zones experience temperatures below 15 °C during much of the year, many supermarkets across the country are ideal candidates for this energy-saving measure.[43]

- **Use electronic expansion valves:** While not explicitly required to enable floating head pressure control, electronic expansion valves (EEVs) allow for finer control over a range of suction pressures. This allows the system to operate at a lower pressure than otherwise available when using standard thermostatic expansion valves (TEVs), which tend to work best at a single suction pressure set point. When working in conjunction with floating head pressure controls, EEVs allow for energy savings over more hours per year.

[43] RSES Journal April 2014, *EEVs Enabling Low Condensing Refrigeration*, Andre Patenaude. https://www.rses.org/assets/rses_journal/0414_Condensers.pdf.

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- **Install variable speed fans on low-temperature condensers:** Most refrigeration systems are designed for worst-case, full-load conditions (high ambient temperature, high humidity). However, most of the time, loads are not at peak, and full capacity is not required. During average conditions, condenser motors either run constantly at a higher speed than necessary or cycle on and off frequently. Producing more capacity than needed wastes considerable energy, and frequent on/off cycling accelerates wear and shortens the useful life of motors and other components. Variable speed-drives (VSDs) can be applied to regulate the operation of condenser fans to provide constant load-matching capacity, saving energy by eliminating over-capacity running. In addition, variable speed operation can result in substantial maintenance savings and prolonged compressor and fan motor lifetimes.
- **Add ambient refrigeration subcooling to condenser circuit:** Reducing the temperature of liquid refrigerant below its condensation temperature is referred to as subcooling. Colder refrigerant results in a higher cooling capacity per unit of refrigerant and/or shorter compressor runtimes, both of which save energy. Subcooling can be achieved by using ambient air or water to remove heat through an oversized cooling tower, or by adding a heat exchanger in the liquid refrigerant section of the condensing circuit.
- **Install digital compressors and controls:** Scroll digital compressors modulate capacity to match loads from 10 to 100%. Conventional compressors run at full capacity and use hot gas bypass under part-load conditions. The ability to modulate compressors reduces energy consumption by up to 30%. Table 3 illustrates the part-load savings.

Table 3. Compressor efficiency, conventional vs. digital

% Full capacity	Hot gas by-pass EER*	Digital scroll EER*	% Improvement
25%	2.9	6.3	117%
50%	5.7	8.2	44%
75%	8.6	10.0	16%
100%	11.5	11.3	n/a

*Energy efficiency ratio

Sobeys Inc. installed new CO_2 refrigerant systems with heat reclamation in 72 of its stores. CO_2 has a lower global warming impact than traditional refrigerants and is less expensive to operate and maintain. The average store reduced carbon dioxide emissions by 62%, electrical consumption by 15% and natural gas consumption by 75%.

Source: Sobeys, http://corporate.sobeys.com/success-stories/.

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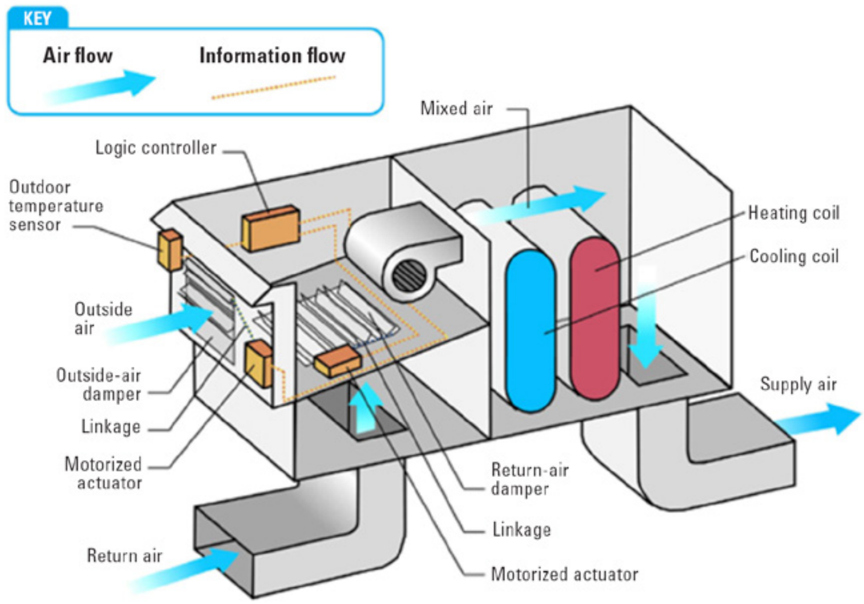
Rooftop units

More than a third of Canadian commercial/institutional building floor space is conditioned by self-contained, packaged rooftop units.[44] RTUs are typically configured with natural gas combustion or electric duct heaters for heating and 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 20.

Figure 20. Typical rooftop unit



Source: U.S. EPA

RTU efficiency has two distinct values: heating and cooling. Because the RTU industry is most prevalent in cooling-dominated climates, RTUs are promoted with their cooling efficiency (i.e. integrated energy efficiency ratio). Heating efficiency has been a lesser focus within the RTU manufacturing industry and is often not published. Furthermore, the RTUs with the highest cooling efficiencies tend to have medium efficiency heating efficiencies and vice versa.

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

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.

Table 4 illustrates how cooling efficiency standards have evolved.

Table 4. 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, Heating and Refrigeration Institute (AHRI), 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, compared to modern RTUs with a range of 12 to 16.8 SEER.

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

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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.

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 & cooling measure list (rooftop units)
Retrofit measures
✓ Convert constant volume system into variable flow system with demand control and economizer
✓ Add compressor control to reduce runtime
✓ Add economizer damper
✓ Modify controls to enable early morning flush during the cooling season
✓ Modify controls to close outside air dampers during morning warm-up during the heating season
Replacement measures
✓ 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 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 17 kW (5 tons), a fully packaged advanced rooftop controller retrofit package that converts a constant volume (CV) system into a variable flow system with demand control and economizer is available. A field study by the Pacific Northwest National Laboratory[45] 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.

[45] Advanced Rooftop Control (ARC) Retrofit: Field Test Results. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf.

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- **Add compressor control to reduce runtime:** For RTUs smaller than 17 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.

- **Add economizer damper:** Some RTU models can accommodate an economizing damper as a manufacturer's option to provide "free cooling" when outdoor air conditions permit (refer to Existing Building Commissioning for more details). In cases where the economizer damper wasn't included in the original product selection, adding the economizer can deliver energy savings. If the existing RTU cannot accept the economizer as a retrofit, a new RTU should be considered.

- **Modify controls to enable early morning flush during the cooling season:** 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.

- **Modify controls to close outside air dampers during morning warm-up during the heating season:** Programming the space temperature set point lower during unoccupied hours is a common practice for energy savings. The temperature is then returned to the occupied period set point before occupants arrive. While warming the space 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.

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.

The Pacific Northwest National Laboratory (PNNL) has created a **Rooftop Unit Comparison Calculator** (**http://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.

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New RTUs should be specified with **energy recovery**. For example, energy or enthalpy wheels allow sensible and latent heat to be recovered from the exhaust air stream and transferred to the incoming cooler, and typically drier, ventilation air. Energy wheels tend to have good heat recovery performance with a sensible effectiveness between 60 and 72% and a latent effectiveness between 50 and 60%.

- **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. When selecting RTU equipment, it is important to understand that the primary efficiency gains are delivered through energy recovery and demand control, followed by cooling, heating and motor efficiency ratings. 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
    - 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 16.8; IEER up to 21
    - Remote energy monitoring and operational supervision

  Condensing type heating RTUs with annual fuel utilization efficiency (AFUE) up to 94% are a special consideration for facilities in very cold climate zones. There are a limited number of manufacturers offering this type of equipment, and the equipment is not paired with high efficiency cooling specifications (such as SEER 16.8, IEER 21). Currently, there are no manufacturers offering the highest heating and cooling efficiency options within a single packaged RTU.

  See the Business Case Guidance section for information on the costs and benefits of two example upgrade scenarios.

Stockroom heating

This section addresses stockroom heating equipment.

Heating & cooling measure list (warehouse heating)
✓ Install infrared heaters
✓ Use 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) found that infrared heaters can reduce the required heat needed to maintain a comfortable temperature in a building (heat load), by at least 15%.[46] 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 stockroom 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 15% can be achieved compared to the ASHRAE 90.1 baseline heating system (an indirect-fired unit heater with combustion products exhausted externally).[47] 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

Figure 21. Infrared heater

[46] 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.

[47] Jim Young, Navigant Consulting Inc. Field Demonstration of High Efficiency Gas Heaters, October 2014. Report prepared for US Department of Energy.

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Domestic hot water

Domestic water heating represents 2% of the energy used in Canadian supermarkets, a relatively minor load. Notwithstanding, there are a number of opportunities to save energy.

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

- **Install low-flow aerators and showerheads:** Reduced flow through faucets and showerheads 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 for faucets and 4.7 L/min for showerheads.
- **Preheat domestic water with heat recovery from refrigeration:** Supermarket refrigeration systems reject heat on an almost continuous basis. This heat can be recovered from the condensing circuit using heat exchangers coupled with the domestic hot water make-up water. Refer to Refrigeration Systems for more details.
- **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. See the Business Case Guidance section for information on the costs and benefits of an example upgrade scenario.
- **Replace storage-based system with on-demand:** Supermarkets typically have only two washrooms (one male, one female). Therefore, 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,[48,49] and the savings are attributed to a lack of storage losses in conventional tank systems.

[48] Natural Resources Canada, Office of Energy Efficiency. Energy Efficiency Ratings. http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=WATERHEATER_T.

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

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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.

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.

PART 1

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 supermarkets and food stores*

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

Email: **nrcan.buildings-batiments.rncan@canada.ca**

Toll-free: 1-877-360-5500

KUDRINKO’S: A CASE STUDY

PART 2

By addressing energy efficiency head on, Kudrinko's cut its energy costs by 40% and its GHG emissions by more than half.

> “I like being a leader in sustainability and the grocery industry in Canada. Of all the things we've done in the last 25 years, energy efficiency is the thing I'm most proud of.”
>
> – Neil Kudrinko, Owner

Kudrinko's is an independent grocery store in Westport, Ontario. The store was built in the early 1960s and was feeling its age. Owner Neil Kudrinko explained that he had seen a substantial increase in his energy costs between 2004 and 2006 and decided that a retrofit was in order.

"Our energy costs had increased by 50% in a very short time," he said. "At the same time, nothing had been done to address the gaps in the building envelope or the old furnace or compressors. Since energy prices weren't going to come down, from a business perspective, the best way to reduce my operating costs was by reducing consumption."

Major benefits

- ✓ Kudrinko's saves about $24,000 per year in fuel and electricity costs.
- ✓ Electricity consumption has been reduced from 480 MWh/year to 395 MWh/year.
- ✓ Switching to propane eliminated the use of 27,000 litres of fuel oil annually.[50]
- ✓ In 2014, Kudrinko’s earned the first Grocery Stewardship Certification (GSC)[51] in Canada.
- ✓ Emissions have been reduced by more than 120 tonnes.

Figure 22. Martha and Neil Kudrinko

Martha and Neil Kudrinko display the store's Commitment to Sustainability.

Photo courtesy of Kudrinko's.

[50] Propane produces fewer GHG emissions than fuel oil.

[51] The GSC program, based in the U.S., was developed to make the grocery sector more sustainable through continuous improvement and employee engagement. http://grocerycert.org/.

PART 2

Getting informed

Neil Kudrinko is nothing if not hands-on. He delights in learning new systems and figuring out what is required to improve them. While studying at Carleton University in Ottawa, he became fascinated with human geography, especially with how the built environment affects the natural environment.

"My work at Carleton really opened my eyes about what was possible," he said. He had returned to university as a mature student while still working at the store, then owned by his father, and began comparing what he was learning to the physical plant at Kudrinko's. "It helped me understand what needed to happen."

That knowledge was invaluable when it finally came time to retrofit the store in 2008; the project included a host of interrelated energy efficiency measures as well as the construction of a new stockroom, which would also house a new HVACsystem.

Some energy-efficient counters had already been installed a few years earlier; however, given the state of the building itself and its systems, Kudrinko said that the equipment made the store feel like "a shiny new sports car but with a four-cylinder engine." But the experience gave Kudrinko a chance to learn.

"I came to know the refrigeration contractor quite well, and I developed a good understanding of the mechanics and principles of those systems and the effects of weather on their operating conditions," he said.

Kudrinko was particularly interested in the amount of GHG emissions produced at the store and began using Carbon Counted, a carbon reporting program started by the Canadian Federation of Independent Grocers (CFIG). Kudrinko said that the program was designed to show the provincial and federal governments that the grocery industry was serious about doing something about climate change.

Carbon Counted showed Kudrinko that, in 2007, his store was responsible for about 195 tonnes of CO_2.

"In addition to the economic benefits of our energy efficiency projects, we have always viewed carbon emission reduction as a key element of our environmental and corporate responsibilities," he explained. "Tracking our CO_2 gave us a reliable baseline so that we could plan our capital investments."

Not all the emissions came from fuel and electricity, however. Prior to the retrofit, for example, a single refrigerant leak in early 2008 emitted nearly the equivalent of 35 tonnes of CO_2. "That one leak was responsible for 20% of our emissions for the year," he said.

Ultimately, high energy costs spurred Kudrinko's decision to perform a full retrofit, and he began collecting quotes for the work and developing an understanding of what the implementation would look like.

PART 2

The retrofit

Although the age of the store was problematic, humidity was the biggest challenge facing Kudrinko's, and it had already led to refrigeration problems. "[Before the retrofit] the store couldn't handle the volume of humidity in summer," said Kudrinko. The front lobby wasn't large enough to create a buffer between the humid outdoor air and the drier indoor air, and the receiving area wasn't airtight, leading to condensation problems inside the store.

By carefully planning the retrofit, Kudrinko was able to leverage all of his investments, not only for better savings, but also to solve those humidity problems.

Mechanical systems

First on the list was how to deal with the in-store oil-burning furnace, which was using upwards of 27,000 litres of furnace oil per year, and had reached the end of its useful life. However, due to the age and construction of the building, Kudrinko says that it would have been too expensive to install a new HVAC system on the store's roof.

"It's a 1964 steel Butler building, and we often got a lot of ice damming on the roof that caused water to leak through," he said. "The building was only designed to hold the weight of the roof and snow, not an HVAC system, so that meant we would have had to install support posts in the floor, which would have created disruption to the store, and would have involved significant cost, about $50,000."

Instead, Kudrinko decided to build a new stockroom and used its roof to house a new and more efficient HVAC system.

Other mechanical improvements included replacing the store's compressors with a Hussman Protocol rack system and two freezers with upright doors.

A $1,500 custom-built heat recovery coil was placed on the cold air return of the furnace so that the store's freezers could redirect excess heat into the store.

"On refrigerators, the heat isn't hot enough to be of much value," Kudrinko explained. "But on low-temperature cases, the heat is hot enough to preheat air through the furnace." In winter, this reclaimed heat reduces the furnace runtime.

Envelope

Before the retrofit, Kudrinko estimated that the store's roof insulation was probably RSI-1.4 (R-8) at most. The roof was retrofitted with an MR24 Butler roofing system.

"It looks like an S-bracket with a rail across the top," Kudrinko explained. "We sealed the original roof and made sure it had no holes, and it became the bottom pan of the new roof." The cavity created between the two roofs was then filled with RSI-7 (R-40) fibreglass insulation, on top of the old insulation. The store's facade was also reconstructed with a stucco finish over rigid foam insulation. To reduce infiltration, air curtains were installed over the front doors.

> "We'd gone from a franchise to being fully independent around that time, so we had changed our procurement processes and we needed more space anyway. Even though we built a new warehouse and increased the physical footprint of the store, we actually reduced energy consumption. It's not always about working within what you have; it's about creating a physical plant to make the changes that you need."
>
> — Neil Kudrinko

PART 2

In-store equipment

New dairy refrigerators were installed in 2015, featuring glass doors and LED lighting, and night-time roller shades were installed on refrigerated cases. "The roller shades keep the cold spillage inside the cases, not outside, and they also help contain cold air during power outages," said Kudrinko. Some energy-efficient refrigerated counters were first installed in 2001; the new counters are 80% more efficient than older models and hold more product. Produce and deli counters were also retrofitted with LEDs and, in 2015, the last of the roller shades were installed on the meat counters.

Old compressors were replaced with a remotely controlled unit that monitors display case temperatures for optimum refrigerant quantity. Before the retrofit was complete, the high humidity levels meant that every two weeks in the summer, coils would ice up, and staff would spend long hours defrosting the cases, leading to wear and tear on product packaging and lost product.

"A probe inside each case measures the temperature every three minutes and adjusts the valve to allow the right amount of refrigerant to efficiently do the job," Kudrinko explained. Besides reducing the amount of cooling required, the probe can detect if a case goes out of the allowable temperature range.

"If that happens, I get an alert and we can get in there and avoid loss of product and get it back into service quicker," he said. "Instead of defrosting every two weeks, we may have to defrost our reach-in ice cream cases maybe once or twice a year."

Lighting

All cases are now lit by LEDs, and some of the store's overhead T8 lighting has been replaced with LED tubes. "Replacing case lighting with LEDs is a no-brainer," said Kudrinko, "but replacing general lighting is still fairly expensive, and I can get better savings in other places. I plan to re-tube [the rest of the store's overhead lighting] with fluorescents one more time and when those tubes are done I hope the economics of switching will be worth it."

Parking lot lighting, however, was a different story. "We spent $250,000 to redo the parking lot, but I wanted to avoid the cost of trenching and laying cable," said Kudrinko. "I started researching solar parking lot lighting and found a company out of Boise, Idaho, that uses photovoltaic film wrapped around the light poles with the batteries at the base." Because there were no certified installers in Canada, Kudrinko took an installers' course and, once the material had been delivered, did the work himself.

LED lighting in the parking lot eliminated on-grid electricity consumption. Motion sensors at the base allow the lights to dim when the area is unoccupied, then brighten when someone comes onto the lot. "They provide enough light for safety and don't contribute to light pollution."

PART 2

Monitoring

Kudrinko tracks energy consumption and refrigerant use, and their associated emissions, and benchmarks those figures against previous years; some of this data is shown in Tables 5 and 6 below.

Table 5. Kudrinko's electricity emissions data

Kudrinko's: Electricity Emissions Data*			
	Quantity (kWh)	CO_2eq (t)	~ Emission Reduction Compared to Baseline (2007)
Baseline (2007)	468,281	98.3	
2008	459,116	78.1	21% lower
2009	434,952	43.9	55% lower
2010	458,892	61.0	38% lower
2011	432,970	57.6	41% lower
2012	446,655	59.4	40% lower
2013	434,817	42.6	57% lower
2014	395,429	38.8	61% lower

Table 6. Kudrinko's total building emissions data

Kudrinko's: Total Building Emissions Data*		
	CO_2eq (t)	~ Emission Reduction Compared to Baseline (2007)
Baseline (2007)	184.8	
2008	119.2	36% lower
2009	76.2	59% lower
2010	94.0	49% lower
2011	92.1	50% lower
2012	92.6	50% lower
2013	77.7	58% lower
2014	73.4	60% lower

*Data has not been normalized for weather conditions.

How were the retrofits financed?

Kudrinko invested $600,000 in the first phase of the retrofit, amortized over 15 years, and $200,000 in the second phase, amortized over 12 years and with a simple payback of about 8 years.

Kudrinko explained that because he knew exactly how many kilowatt hours and how much propane his store used annually, he could easily compare energy consumption and energy costs pre- and post-retrofit. "I could also calculate how much I would have spent had I done nothing," he said. "That's a far better exercise than simply looking at what my costs are today."

Community and employee engagement

Kudrinko said that once he began to make physical and financial investments in energy efficiency, employees were far more receptive to the cultural and operational changes needed, because they saw it as being in concert with the strategic goals of the company.

"We used to come in first thing in the morning—sometimes 6 a.m. even though we don't open till 8—and turn on all the lights. We started energy discussions with our employees, and we realized how few lights we actually needed on."

Kudrinko said that customers also noticed some of the changes. "I hear people pointing out the parking lot lights and telling others that they're off-grid solar," he said, adding that of all the measures he's done, the solar lighting is the one that customers notice the most.

Kudrinko's is also active in sustainability issues within the wider community. It prints its flyers on 100% recycled paper, encourages food education through its Family Meals Month in association with the Food Marketing Institute, hosts food education tours for local schools, is a consultant for the Two Rivers Food Hub,[52] and has provided multi-year funding for visitor upgrades to the Foley Mountain Conservation Area.[53]

Figure 23: Local food display

In 2015, Kudrinko's launched the Localize labelling system to highlight locally grown and produced foods.

Photo courtesy of Neil Kudrinko.

[52] The Two Rivers Food Hub, a non-profit organization, connects buyers and sellers of local food in the Lanark, Leeds and Grenville counties. http://tworiversfoodhub.com/.

[53] Part of the Rideau Valley Conservation Authority, the Foley Mountain Conservation Area runs educational programs for school children and youth groups. http://www.rvca.ca/careas/foley/.

Advice

Kudrinko said that the best way for grocery store owners to start is by benchmarking their stores and comparing their performance, either to other organizations or to their stores' own historical performance. He cited ENERGY STAR Portfolio Manager as an excellent benchmarking program for larger grocery store chains that have several outlets, but still very useful for independent stores.

"The Carbon Counted data let me do that and it made me accountable," he said. For Kudrinko, doing a retrofit wasn't about just the cost, but also the avoided cost of energy consumption. "A kilowatt hour is a kilowatt hour; a litre of propane is a litre of propane. I don't control those costs, but I can control my consumption."

Kudrinko advised owners to better understand the risks to their business and develop a plan to deal with those risks. "Some companies only see their costs per kilowatt hour, but what if those costs go up? Businesses are going to have to spend more anyway. I've opted to protect myself and when costs increase, I have an advantage over my competition."

PART 3

BUSINESS CASE GUIDANCE

Every building and retrofit situation is unique, and buildings should be properly assessed by a professional energy auditor before making any retrofit decisions. Refer to Section 2 of the Principles Module for guidance on how to independently assess the business case for retrofit measures at your facility.

This section provides general information on the costs and benefits for select retrofit measures based on example upgrade scenarios.

Business case analysis methodology

Cost-benefit information has been calculated or modelled for each example retrofit measure using a number of general input assumptions. To develop **annual savings estimates**, upgrade measures were analyzed under conditions typical of a 30-year-old, 5,000-m^2 supermarket. Energy models were created in eQUEST (Quick Energy Simulation Tool) v3.65 to evaluate the whole-building impact of a proposed measure over the entire year. For example, the baseline models use minimum building envelope design criteria (e.g. U-values) from the Model National Energy Code for Buildings (MNECB), while the building envelope measures are modelled based on the National Energy Code for Buildings (NECB 2011) requirements. The models use climate data from Vancouver, Edmonton and Montreal to represent example Canadian climate conditions.

To develop measure **cost estimates**, cost data was sourced from industry-accepted pricing guides and from discussions with manufacturers. In most cases, cost increments between a "standard" and "upgrade" case (incremental costs) are presented and used in the cost-benefit analysis, while full upgrade costs are listed to provide further context. In cases where a standard option is not applicable, only full upgrade costs are considered.

Lastly, to develop net present value (**NPV**), internal rate of return (**IRR**) and **simple payback**[54] estimates, marginal utility rate data was sourced from the three cities above.[55] For the purposes of this analysis, it was assumed that existing equipment was replaced at the end of its useful life. Note that for some measures with strong internal rates of return, it may make sense to consider early replacement.

[54] See Section 2, Building Energy Management Planning, of the Principles Module for definitions of NPV, IRR and simple payback.

[55] Vancouver: $0.000356 per incremental GJ of electricity, and $7.367 per incremental GJ of natural gas. Edmonton: $0.000291 per incremental GJ of electricity, and $5.296 per incremental GJ of natural gas. Montreal: $0.000221 per incremental GJ of electricity, and $10.399 per incremental GJ of natural gas.

Example measures

Cost, savings, and financial metrics are presented in tabular form for each example measure. Specific assumptions and notes are provided following each table.

While some of the measures below appear to have poor financial metrics for the cases analyzed, this does not suggest that these measures are not worth considering in specific cases, or as part of a comprehensive retrofit. Consider assessing the business case for a comprehensive major retrofit project by performing a cost-benefit analysis on the proposed project as a whole, or for a package of interrelated measures.

Lighting upgrade

Replace HID lighting with high bay fluorescent or LED (per fixture)

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	3.3	$105	$92	$1,056	89.5%	1.1
Edmonton	3.3	$105	$75	$842	73.4%	1.4
Montreal	3.3	$105	$57	$614	56.1%	1.8

Measure-specific assumptions and notes:

- Based on replacement of 400-W MH with 250-W LED
- 13 hours/day, 357 days/year
- Full replacement cost estimate is $650

Replace incandescent and fluorescent lamps with LED (per fixture)

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	0.7	$7	$18	$219	258.0%	0.4
Edmonton	0.7	$7	$15	$178	210.9%	0.5
Montreal	0.7	$7	$11	$133	160.5%	0.6

Measure-specific assumptions and notes:

- Based on replacement of 50-W MR16 with 11-W LED
- 13 hours/day, 357 days/year
- Full replacement cost estimate is $12

Replace incandescent exit signs with LED type (per fixture)

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	0.3	$25	$9	$85	36.4%	2.9
Edmonton	0.3	$25	$7	$65	29.7%	3.5
Montreal	0.3	$25	$5	$43	22.1%	4.6

Measure-specific assumptions and notes:

- Based on replacement of 11-W CFL with 1-W LED
- 24 hours/day, 365 days/year
- Full replacement cost estimate is $50

Replace building exterior and parking lot lighting with LED (per fixture)

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	5.1	$165	$141	$1,621	87.7%	1.2
Edmonton	5.1	$165	$115	$1,293	71.9%	1.4
Montreal	5.1	$165	$88	$941	55.0%	1.9

Measure-specific assumptions and notes:

- Based on replacement of 400-W HPS (high-pressure sodium) with 138-W LED
- 12 hours/day, 365 days/year
- Full replacement cost estimate is $850

Add photocell and timeclock controls to exterior lighting

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	21.8	$1,630	$598	$5,930	38.3%	2.7
Edmonton	21.8	$1,630	$488	$4,540	31.3%	3.3
Montreal	21.8	$1,630	$370	$3,051	23.4%	4.4

Measure-specific assumptions and notes:

- Based on addition of timeclock in series with PC control for twenty 138-W LED fixtures
- Saving 6 hours/day, 365 days/year

Supplemental load reduction

Wall insulation, slab edge insulation, infiltration reduction

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	716.3	$160,166	$5,096	-$47,663	1.6%	31.4
Edmonton	880.8	$165,696	$4,579	-$64,617	0.7%	36.2
Montreal	878.4	$160,473	$9,039	$39,076	5.7%	17.8

Measure-specific assumptions and notes:

- Vancouver wall insulation upgraded from RSI-1.233 (R-7) to RSI-3.170 (R-18)
- Edmonton wall insulation upgraded from RSI-2.078 (R-11.8) to RSI-4.755 (R-27)
- Montreal wall insulation upgraded from RSI-1.814 (R-10.3) to RSI-4.051 (R-23)
- Slab edge insulation upgraded from no insulation to 1.2 m of RSI-1.409 (R-8)
- Infiltration reduction from 1 L/s per m^2 of wall area (0.2 cfm per sq. ft. of wall area) to 0.2975 L/s per m^2 of wall area (0.0595 cfm per sq. ft. of wall area)

Roof insulation

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	425.4	$50,516	$3,519	$27,177	7.5%	14.4
Edmonton	378.5	$51,340	$2,276	-$1,088	3.8%	22.6
Montreal	262.0	$49,187	$2,788	$12,353	5.7%	17.6

Measure-specific assumptions and notes:

- Vancouver roof insulation upgraded from RSI-2.113 (R-12) to RSI-3.698 (R-21)
- Edmonton roof insulation upgraded from RSI-3.452 (R-19.6) to RSI-6.173 (R-35)
- Montreal roof insulation upgraded from RSI-3.452 (R-19.6) to RSI-5.464 (R-31)

Windows

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	42.2	$28,018	$313	-$21,109	-4.2%	89.5
Edmonton	64.5	$28,275	$336	-$20,847	-3.9%	84.0
Montreal	55.8	$26,972	$574	-$14,295	-0.8%	47.0

Measure-specific assumptions and notes:

- Window U-value upgraded from 3.5-W/m$^2 \cdot$K (0.62 Btu/hr-sq. ft.$\cdot$°F) to 2.0-W/m$^2 \cdot$K (0.35 Btu/hr-sq. ft.$\cdot$°F)

Heating and cooling resizing and replacement

Refrigeration – medium temperature display cases

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	500.4	$70,875	$13,761	$102,986	19.6%	5.2
Edmonton	500.4	$70,875	$11,231	$71,024	15.3%	6.3
Montreal	500.4	$70,875	$8,521	$36,779	10.3%	8.3

Measure-specific assumptions and notes:

- Equipment: 25 open dairy cases (4 shelves, 3.65 m long), plus 25 closed reach-in coolers (3.65 m long)
- Retrofit case: ECM evaporator motors, LED lighting, anti-sweat heater control (store environment @55% RH)

Refrigeration – low temperature display cases

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	432.0	$49,125	$11,880	$100,971	25.0%	4.1
Edmonton	432.0	$49,125	$9,696	$73,378	20.0%	5.1
Montreal	432.0	$49,125	$7,356	$43,813	14.2%	6.7

Measure-specific assumptions and notes:

- Equipment: 25 closed reach-in freezers (3.65 m long)
- Retrofit case: ECM evaporator motors, LED lighting, anti-sweat heater control (store environment @55% RH)

Refrigeration system heat recovery (to domestic hot water)

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	365.0	$5,000	$2,639	$28,347	54.7%	1.9
Edmonton	365.0	$5,000	$1,897	$18,973	39.6%	2.6
Montreal	365.0	$5,000	$3,726	$42,073	76.5%	1.3

Measure-specific assumptions and notes:

- Equipment: Heat recovery from refrigeration condensing circuit
- Retrofit case: Heat recovery water heater; heat rejected exceeds heat required for domestic hot water, so savings capped at annual domestic hot water consumption

RTU with condensing type heating

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	641.3	$229,660	$4,543	-$172,261	-10.8%	50.6
Edmonton	1,524.5	$229,660	$9,961	-$103,810	-3.3%	23.1
Montreal	1,606.3	$229,660	$17,072	-$13,970	3.2%	13.5

Measure-specific assumptions and notes:

- Applicability: best suited for climate zones 7a-8, and high outdoor air applications
- Equipment: 35-kW (10-ton) rooftop air handling unit (5 RTUs included)
- Base case: 80% heating efficiency, 12.1 IEER
- Measure case: 91% heating efficiency, 12.1 IEER, enthalpy wheel, DCV, dual enthalpy economizer
- Full replacement cost estimate is $332,050

High-efficiency RTU

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	337.3	$41,600	$7,873	$57,871	19.1%	5.3
Edmonton	1,220.4	$41,600	$12,848	$120,729	32.3%	3.2
Montreal	1,248.2	$41,600	$14,663	$143,655	36.8%	2.8

Measure-specific assumptions and notes:

- Equipment: 35-kW (10-ton) rooftop air handling unit (5 RTUs included)
- Base case: 80% heating efficiency, 12.1 IEER
- Measure case: 81% heating efficiency, 19.1 IEER, enthalpy wheel, DCV, dual enthalpy economizer
- Full replacement cost estimate is $143,990

Domestic hot water tank

Example City	Annual Savings Estimate (GJ)	Incremental Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Incremental Simple Payback (yrs)
Vancouver	54.3	$5,290	$392	-$332	3.1%	13.5
Edmonton	59.1	$5,290	$307	-$1,412	0.0%	17.2
Montreal	63.9	$5,290	$652	$2,953	10.7%	8.1

Measure-specific assumptions and notes:

- Equipment: 450-litre domestic water heater (gas-fired)
- Base case: 80% thermal efficiency
- Measure case: 97% thermal efficiency
- Full replacement cost estimate is $14,045

PART 4 MY FACILITY

The following take-away section provides a summary of the retrofit measures applicable to food 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 ENERGY STAR score.

The appropriate next steps for your facility will vary depending on your ENERGY STAR score:

- If your facility has a **low score**, 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 an **average score**, 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 **high score**, you should focus on **maintaining** your score. 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*.

ENERGY STAR score: 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 score may choose to focus primarily on Maintain measures.

PART 4

Instructions

1. Benchmark your facility using ENERGY STAR Portfolio Manager and determine your ENERGY STAR score.
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 labelled:

❑ **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

ENERGY STAR PORTFOLIO MANAGER INPUTS

Gross Floor Area: ____________________

# of Workers (main shift): ____________________

Length of Display Cases: ____________________

# of Cash Registers: ____________________

# of Computers: ____________________

ENERGY STAR PORTFOLIO MANAGER OUTPUTS

ENERGY STAR Score: ____________________

Site EUI: ____________________

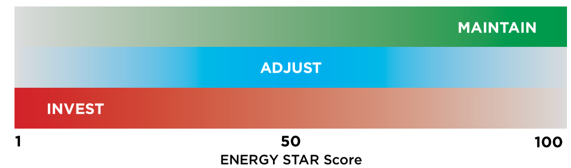
Source EUI: ____________________

Median Property EUI: ____________________

TARGETS

ENERGY STAR Score Target: ____________________

Site EUI Target: ____________________



Supermarkets – Opportunity Questionnaire

EBCx

- Do the lighting and occupancy schedules match? [Pg. 8]
- Is the air handling system on a schedule? [Pg. 8]
- Are the zone temperature set points set back/ forward during unoccupied hours? [Pg. 8]
- Does the RTU have a properly functioning economizer to enable free cooling? [Pg. 9]
- Is the supply air temperature reset dependent on outdoor conditions? [Pg. 9]
- Has humidity control been calibrated? [Pg. 9]

Lighting upgrades

Retail

- Have existing fixtures or lamps been replaced with LED lamps? [Pg. 20]
- 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]
- Is lighting circuited for after-hours activities? [Pg. 20]

Stockroom and Staff Areas

- Have existing fixtures or lamps been replaced with LED lamps? [Pg. 22]
- Have incandescent Exit signs been replaced with LED signs? [Pg. 22]
- Have wall switches in enclosed rooms been replaced with occupancy/vacancy sensors? [Pg. 22]
- Has HID lighting been replaced with high-bay fluorescent or LED lighting? [Pg. 22]

Supplemental load reduction

Power loads and equipment

- Is equipment being turned off when not in use? [Pg. 23]
- Is ENERGY STAR equipment being used where applicable? [Pg. 23]
- Has an employee energy awareness program been implemented? [Pg. 25]
- Has kitchen equipment been replaced with efficient fixtures and appliances? [Pg. 24]
- Have transformers been replaced with energy-efficient models? [Pg. 25]

Envelope

- Have infiltration issues been addressed? [Pg. 27]
- Has an air barrier been added or improved? [Pg. 28]
- Do roof and wall insulation levels meet NECB requirements? [Pg. 29]

Air distribution systems upgrade

- Have high-induction swirl diffusers been installed in retail areas? [Pg. 38]
- Has heating been eliminated from front entrance vestibules? [Pg. 40]
- Is there a DCV system? [Pg. 37]
- Have air turbines for destratification in retail areas been installed? [Pg. 38]
- Have destratification fans been installed in stockrooms? [Pg. 38]
- Has DX dehumidification been replaced with desiccant? [Pg. 40]

Heating and cooling resizing and replacement

Rooftop units

- Is an early morning flush performed regularly during the cooling season? [Pg. 51]
- Are the outside air dampers closed during morning warm-up during the heating season? [Pg. 51]
- Has the CV system been converted to a variable flow system with demand control and an economizer? [Pg. 50]
- Have compressor controllers been installed on the RTU to reduce runtime? [Pg. 51]
- Has an economizer damper been added? [Pg. 51]
- Have old RTUs been replaced with new high-efficiency units? [Pg. 52]

Stockroom Heating

- Have infrared heaters been installed? [Pg. 53]
- Have direct-fired, blow-through heaters been installed in spaces with mechanical exhaust systems? [Pg. 53]

- ❑ Are fan belts and pulleys operating at proper tension? [Pg. 9]
- ❑ Have the BAS sensors been calibrated recently? [Pg. 10]
- ❑ Have supply and exhaust air imbalances been corrected? [Pg. 10]
- ❑ Has missing or damaged pipe insulation been repaired? [Pg. 10]
- ❑ Is the ductwork sealed to prevent leakage? [Pg. 10]
- ❑ Have refrigeration leaks been investigated and corrected? [Pg. 10]
- ❑ Have display case temperature controls been checked and adjusted? [Pg. 10]
- ❑ Has the defrost cycle been optimized? [Pg. 11]
- ❑ Has the refrigeration condensing circuit heat recovery operation been checked? [Pg. 11]

- ◇ Have daylight sources and lighting control been installed? [Pg. 22]
- ◇ Have occupancy sensors been installed? [Pg. 22]

Exterior / parking lot

- ❍ Has exterior and parking lot lighting been replaced with LED lighting? [Pg. 23]
- ◇ Are photocell or timeclock controls being used? [Pg. 23]

- ◇ Have the windows and doors been upgraded? [Pg. 29]
- ◇ Have high-speed doors and/or air curtains been installed? [Pg. 31]
- ◇ Does the building have a "cool roof"? [Pg. 30]
- ◇ Have loading dock seals been added? [Pg. 31]
- ◇ Has a front entrance vestibule been added? [Pg. 31]

Domestic hot water

- ❍ Have low-flow aerators and showerheads been installed? [Pg. 54]
- ◇ Is water being preheated with heat recovery from the refrigeration circuit? [Pg. 54]
- ◇ Has the hot water heater been replaced with a high-efficiency unit? [Pg. 54]
- ◇ Have storage-based hot water systems been replaced with tankless? [Pg. 54]

Refrigeration System Measures

Display Cases

- ❍ Are night curtains being used on open medium-temperature cases during unoccupied hours? [Pg. 42]
- ❍ Are anti-sweat heaters controlled to cycle based on dew point? [Pg. 42]
- ❍ Has lighting been replaced with LED lamps? [Pg. 43]
- ◇ Have doors been installed on medium-temperature cases? [Pg. 41]
- ◇ Is demand defrost control being used? [Pg. 42]
- ◇ Have compressors been centralized and located away from retail areas? [Pg. 43]
- ◇ Have evaporator fan motors been replaced with ECMs? [Pg. 43]

Walk-In Coolers and Freezers

- ❍ Are o Are fans turned off while doors are open? [Pg. 44]
- ❍ Have strip curtains been installed? [Pg. 45]
- ❍ Are compressors turned off while doors are open? [Pg. 45]
- ❍ Have closures been added to doors? [Pg. 45]
- ❍ Is air defrost being leveraged for medium-temperature coolers? [Pg. 45]
- ❍ Has lighting been replaced with LED lamps? [Pg. 45]
- ◇ Has insulation been upgraded? [Pg. 44]
- ◇ Are advanced electric defrost controls being used for low-temperature freezers? [Pg. 44]
- ◇ Have two-speed evaporator fans been installed? [Pg. 44]
- ◇ Have evaporator fan motors been replaced with ECMs? [Pg. 44]
- ◇ Has a free cooling system been installed? [Pg. 44]

Compressor Systems

- ◇ Is heat being recovered from the condensing circuit? [Pg. 46]
- ◇ Has floating head pressure been reduced? [Pg. 46]
- ◇ Have EEVs been installed? [Pg. 46]
- ◇ Has the condenser system been converted into a hybrid system? [Pg. 46]
- ◇ Have variable speed fans been installed on low-temperature condensers? [Pg. 47]
- ◇ Has ambient refrigeration subcooling been added to condenser circuits? [Pg. 47]
- ◇ Have compressors been replaced with new digital equipment and controls? [Pg. 47]