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Major Energy Retrofit Guidelines

for Commercial and Institutional Buildings

FOOD STORES

Canada

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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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ENERGY RETROFIT OPPORTUNITIES IN FOOD STORES

PART 1

The Food Stores 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 food stores.

The Food Stores Module is divided into four parts:

1. **Retrofit Opportunities in Food Stores:** Provides an overview of Canadian food stores. 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.

MAJOR ENERGY RETROFIT GUIDELINES: PRINCIPLES

FOOD STORES MODULE

Food stores can be free standing stores, located in open air or strip centres, or in malls. Examples of store types are convenience stores with or without gas stations, meat markets, fish and seafood markets, fruit and vegetable markets, baked goods stores, and beer, wine and liquor stores. 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.

Figure 1. Butcher shop store front

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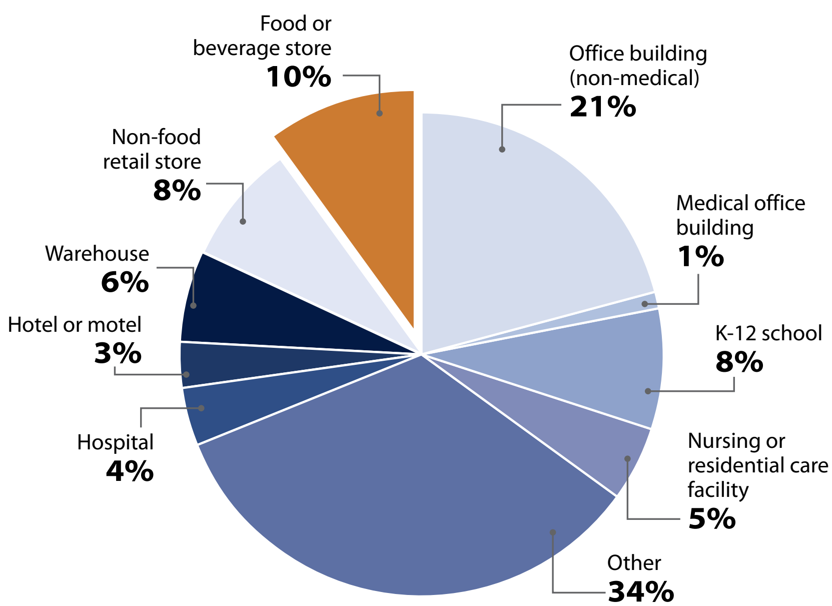
Food stores overview

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 2. Commercial/institutional energy use by subsector



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

Figure 2 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 latter being the focus of this module.

Food store owners understand that they must create an inviting space for customers while also maintaining appropriate conditions for the food and beverage products being sold. Luckily, there are many ways to improve the environment for customers and merchandise, while also addressing energy efficiency. For example, many food stores have 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 compressor systems.

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

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

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Figure 3. Gelato freezer

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).

Food store lighting is designed to attract customers, provide sufficient lighting for the evaluation of merchandise, and facilitate completion of the sale. Lighting is often a key element of a store's atmosphere and helps to communicate the retailer's brand image. As outlined later in this module, measures including LED lighting technology and skylights can improve the store's atmosphere, reduce energy consumption and, in some cases, even increase sales.

Free cooling is another example unique to food stores with walk-in coolers or freezers. Retrofitting walk-ins with a free cooling system allows you to take advantage of cold outside air during winter months, resulting in energy savings and less wear and tear on the walk-in compressor system.

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.

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There are numerous reasons why you may be initiating a major retrofit in your facility. You may be experiencing increasing complaints from neighbours about the brightness of exterior lighting overnight, or from staff and customers about the temperatures within the store. Major capital equipment or building infrastructure, such as your refrigerated display cases 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.

Opportunities

Energy savings are one of the principal benefits of a major retrofit project. Energy savings lead to reduced energy costs, which directly improves your bottom line. In other words, the profitability of your store will improve as you reduce your operating costs through lowered energy consumption. Lower energy consumption also limits your vulnerability to energy price fluctuations and reduces your greenhouse gas emissions.

Beyond energy savings, a notable benefit of major energy retrofits is often an improved corporate and community image. Food stores 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 food stores can face several challenges:

- Limited physical space: Food stores are typically a composite of several uses within a relatively confined space. They often have retail and supermarket-like spaces, office spaces, and storage spaces, which can lead to energy-related challenges. For example, it may not be possible to install air-cooled refrigeration equipment in a well-ventilated part of the store, causing heat to be retained, and in turn, increasing cooling requirements.
- Access to capital funding: Competition for funding poses a real challenge for food stores, 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 food stores 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.

- Shared building systems: For food stores located in strip malls, major retrofits are likely to need special consideration. The ability to upgrade some or all of the building equipment in a particular space will depend on lease agreements, whether spaces are served by their own HVAC or other systems, and the building owner's willingness to participate in the process.
- Split incentive: For all non-owner occupied buildings, common leasing arrangements can also pose a barrier to implementing energy retrofits because of the disconnect between who pays for the retrofits and who receives the benefits. Such an arrangement is commonly referred to as a "split incentive" between the owner and the tenant. As a result, when it comes to financing energy retrofits, building owners and tenants often perceive the negotiation process as a zero-sum game of winners and losers, where one party pays while the other benefits. A survey of decision makers responsible for energy use in buildings and published by the Institute for Building Efficiency in 2012[3] identified split incentives as one of the barriers to capturing energy savings in buildings.

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

Two organizations have developed guides and templates for green leases.

- The Real Property Association of Canada's (RealPAC) *Green Lease Guide for Commercial Tenants*, available on their website: **http://www.realpac.ca/?page=GreenLeaseGuidefo**
- Building Owners and Managers Association's (BOMA) *Commercial Lease: Guide to Sustainable and Energy Efficient Leasing for High-Performance Buildings*, available for sale on their website: **http://store.boma.org/products/commercial-lease-guide-to-sustainable-and-energy-efficent-leasing-for-high-performance-buildings**

The BC Liquor Distribution Branch (BCLDB) uses green leases to specify levels of energy efficiency, e.g. lighting types, when doing retrofits or when siting a new location. It is viewed as a "living document" that changes to reflect new technologies or circumstances.

Source: David McPhie, Environmental Initiatives Manager, BC Liquor Distribution Branch

Energy use profile

The energy consumption profile of a food store is a function of the mix of building types present in a given store, which may include retail, supermarket, and in some cases, gas station. While some food stores lean toward the grocery spectrum with more refrigeration usage, others have more extensive food service and preparation areas.[4]

[3] Institute for Building Efficiency. http://www.institutebe.com/InstituteBE/media/Library/Resources/Energy%20Efficiency%20Indicator/2012-EEI-Global-Results-Presentation.pdf.

[4] Smart Energy Design Assistance Centre. 2011. *Energy Smart Tips for Convenience Stores.*

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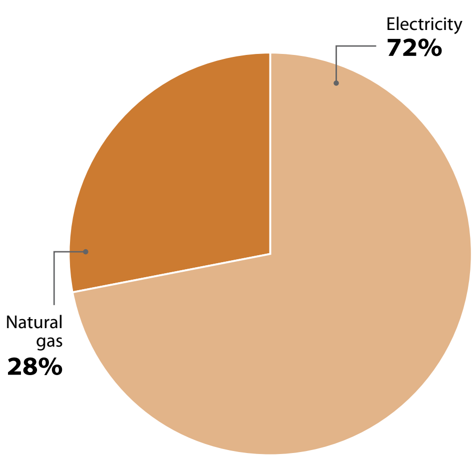
When planning your major retrofit project, consider the energy use profile for a typical Canadian food store. Although specific energy use profiles will vary depending on the type of services available on site, the example below can be used to provide a general indication of how you use your energy.

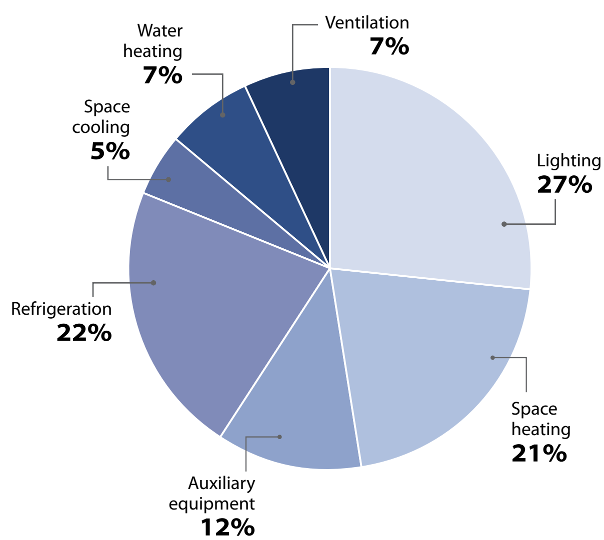
Figure 4 shows the breakdown of consumption by energy source. In this example, electricity provides approximately 70% of the store's energy requirements. Figure 5 shows the breakdown of consumption by end use. Lighting is the largest end use, followed by refrigeration, space heating, and auxiliary equipment (e.g. food service equipment, other plug loads and computer equipment).

Figure 4. Energy use by energy source



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

Figure 5. Energy use by end use



Natural Resources Canada EBI and ecoEnergy data

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.

The national median site energy intensity for food stores in Canada is 3.1 GJ per square metre.[5] That is, half of Canadian food stores 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 food stores 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.[6]

[5] United States Environmental Protection Agency. 2014. *Canadian Energy Use Intensity by Property Type.*

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

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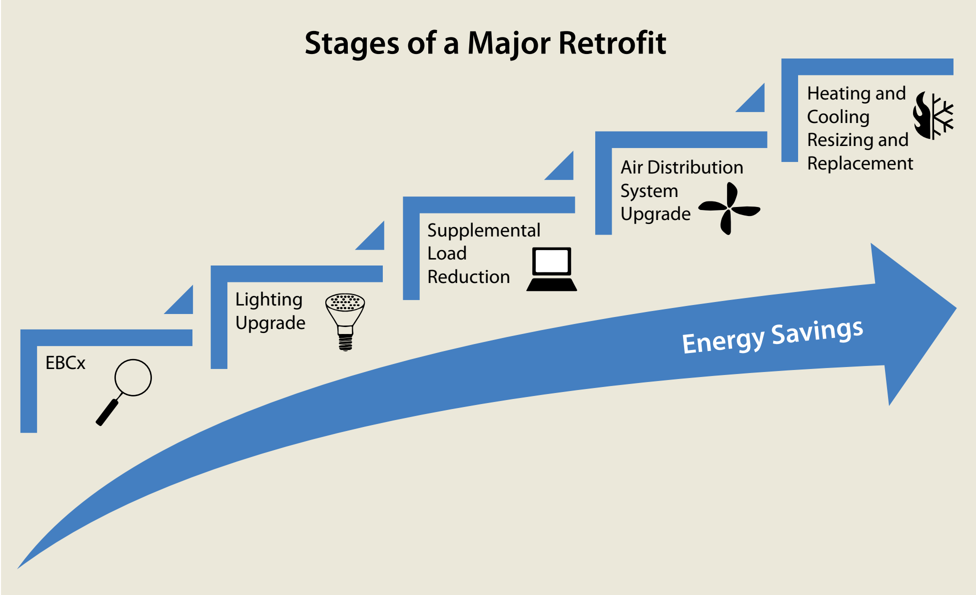
Figure 6. Vegetable market

Building owners are encouraged to benchmark and track their energy performance using ENERGY STAR Portfolio Manager, the most comprehensive and only standardized energy benchmarking tool in Canada. 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.

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.

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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.[7]

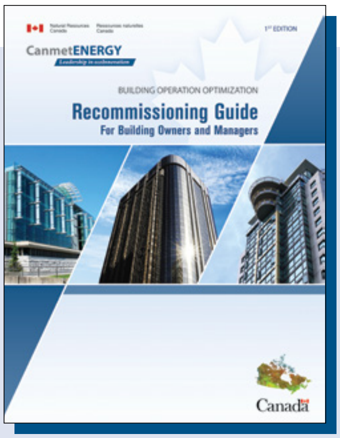
Savings from commissioning are achieved by improving building operations and restructuring maintenance procedures. Natural Resources Canada's (NRCan) *Recommissioning Guide for Building Owners and Managers*[8] shows you how to reduce operational expenses and increase revenue through improved building 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 food stores, 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.[9]



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.

[7] 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.

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

[9] 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. 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

- **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.

Couche-Tard/Mac committed capital for energy management improvements in its convenience stores. Its "One-Touch" energy program first identified, then implemented energy-efficient improvements, such as lighting retrofits and optimization of its stores' HVAC systems. In planning the projects, the company considered energy efficiency rebates and which building systems would have the greatest energy impact. For each store, most retrofits took a single visit, limiting the impact on store operations. Over the course of the five-year program, the company has cut electrical consumption by 11.4%, or 1 billion kilowatt hours.

Source: Couche-Tard, http://corpo.couche-tard.com/en/corporate-responsibility/environmental-responsibility/

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

Information: www.retailcouncil.org

- **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.[10]

  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.[11]

- **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.[12] Furthermore, maintaining the relative humidity between 40 and 45% results in 10 to 15% savings in the display case operation.[13]

- **Check fan belts and pulleys for tension and wear:** Typical losses from belt-driven fans can be 2 to 6%.[14] 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.

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

[11] 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.

[12] 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%.

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

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

- **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.
- **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.

Figure 7. HVAC pipe insulation

- **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 food store 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:** Food store refrigeration systems can sometimes 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.[15] 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*.[16]
- **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.

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

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

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

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- **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.[17]

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.

Lighting upgrades

Lighting consumes close to 30% of the energy used in Canadian food stores and affects other building systems through its electrical requirements and the waste heat it produces. Upgrading lighting systems with efficient light sources, fixtures and controls reduces lighting energy use, improves the visual environment, and can impact the sizing of HVAC and electrical systems.

Lighting upgrades are often attractive investments with relatively low capital costs and short paybacks. Even simple upgrades can reduce lighting energy consumption between 10 and 85%[18] 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.

[17] 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.

[18] 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.

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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 Illuminating Engineering Society of North America (IESNA)[19] recommends an illuminance target of 500 lux[20] for general retail[21] spaces. 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 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.

Lighting measures are discussed in the context of two typical food store environments: Interior, and Exterior/Gas Canopy/Parking Lot lighting.

Interior

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.

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.

[19] The Lighting Handbook, 10th Edition, Illuminating Engineering Society of North America.

[20] 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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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.

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 reflects their brand image:

- Retailers selling high-quality or exclusive products and specialized services will focus on lighting that reflects their image. Warm light sources with low levels of general (ambient) lighting and high-intensity accent lighting are often used to create a comfortable atmosphere that encourages customers to browse and spend longer periods of time in the store, which usually equates to spending more money.
- Retailers who promote low prices and a wide range of merchandise will use basic lighting systems with uniform light levels and cool temperatures. This type of lighting approach supports the message that customers are getting the best deals and not paying for the retailer's high overhead costs in the products they purchase.

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.

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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.

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. 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.

Display & 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.

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

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- 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 off) in less than 1.5 seconds, while MH lamps take approximately 17 minutes. This is an important factor if daylighting and other lighting control strategies are implemented. For example, on days where daylighting is highly variable, the delayed response of MH fixtures may produce undesirable lighting conditions. LED lamps are instant-on and do not have a warm-up period.

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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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.

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

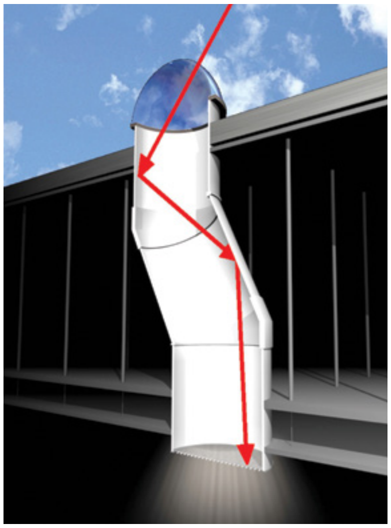
Energy savings are available with well-designed daylighting when coupled with a daylight-responsive lighting control system. When there is adequate ambient lighting provided from daylight alone, this system has the capability to reduce electric lighting power. Other benefits include:

- *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.

Figure 8. Sealed dome skylight

Source: Wikimedia Commons (User: Masur)

Figure 9. Light tube skylight



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

[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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- *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.

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 (interior)
✓ Replace existing light fixtures or lamps with LED lamps
✓ Replace incandescent Exit signs with LED signs
✓ Replace wall switches in enclosed rooms with occupancy/vacancy sensors
✓ Install daylight sources and lighting control

- **Replace existing light fixtures or lamps with LED lamps:** Replacement LED lamps and fixtures are available for a wide range of existing fixtures. Table 1 provides examples of replacements for fixtures common in food stores.

Case in point:
7-11 Stores

Switching to LED lighting at 1,600 properties has saved 7-11 stores more than $2 million per year in energy and maintenance costs. Store lighting was upgraded to LED canopy and area lights and wall packs from what had been mostly 400-W MH fixtures with low colour rendering.

Source: GE Lighting, **http://www.gelighting.com/LightingWeb/na/images/VERT008-GE-Retail-LED-Lighting-7-Eleven-Case-Study_tcm201-86636.pdf**.

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Table1. Replacement examples for common fixtures

Existing fixtures			LED replacement		Demand savings
Type	Fixture wattage	Lumens	Fixture wattage	Lumens	%
MR16	50 W	600	9 W	620	82%
CFL	13 W	500	5 W	500	62%
T8	61 W[24]	4658[25]	34 W	4000	44%
MH	85 W (70-W lamp)	4400	50 W	4100	41%

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.
- **Replace wall switches in enclosed rooms with occupancy/vacancy sensors:** Occupancy and vacancy sensors turn lights off when spaces are empty. Occupancy sensors automatically turn lights on when occupancy is detected; vacancy sensors require manual activation of the wall switch to turn lights on. Vacancy sensors deliver the highest savings since the lights will never automatically turn on. A time-out period of 15 minutes is typical to avoid short cycling and reduced lamp life. The U.S. EPA estimates savings potential under optimal conditions ranging from 25 to 75% of lighting energy depending on space type.[26]
- **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.

Petro-Canada has used LED border tubes in its under-canopy lighting for more than a decade. In its initial pilot test, managers found a 15% decrease in electricity compared to neon lighting.

Source: LEDs Magazine, http://www.ledsmagazine.com/articles/2005/02/case-study-canopy-border-lighting-for-gas-stations.html.

[24] Two 32-W lamps with 0.95 ballast factor.

[25] Mean lumens presented for both T8 and MH fixtures.

[26] 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 / gas canopy / parking lot

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

Figure 10. Gas canopy lighting

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

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

Figure 11. LED parking lot lighting

- **Replace building exterior, gas canopy, 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.

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Supplemental load reduction

Supplemental load sources are secondary load contributors to energy consumption in buildings (occupants, computers and equipment, the building 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 food store environment.

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

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

Many food stores that offer prepared foods operate small commercial kitchens. A wide range of equipment, fixtures, and appliances contribute to energy consumption in 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*[27] can help owners and managers develop successful employee energy awareness programs. Another useful resource is the ENERGY STAR Guidelines for Energy Management.[28] 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.

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 12 shows how heat flows into and out of a building through the envelope.

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

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

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

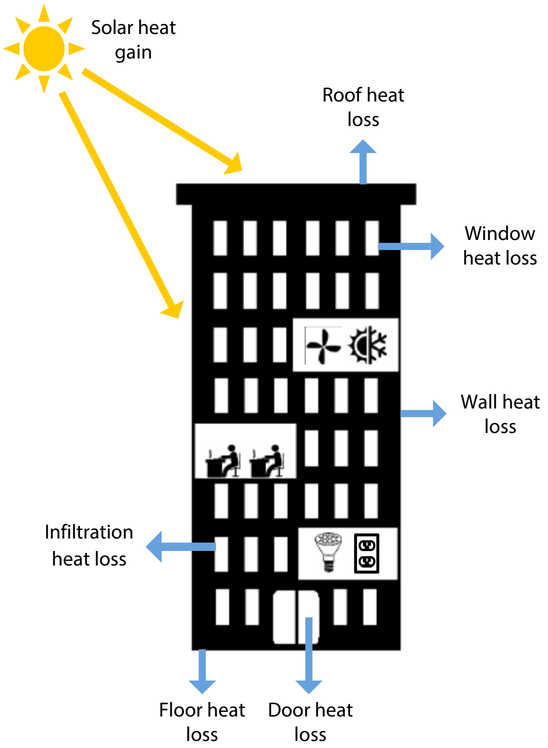
Conversion:

RSI = R ÷ 5.678

R = RSI × 5.678

1 RSI = R-5.678

Figure 12. Building envelope heat transfer



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

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

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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
✓ Add a vestibule

- **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 13 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 square metre of wall area (0.4 cubic feet per minute per square foot of wall area) at a pressure difference of 75 Pa (0.3 inches water column).

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

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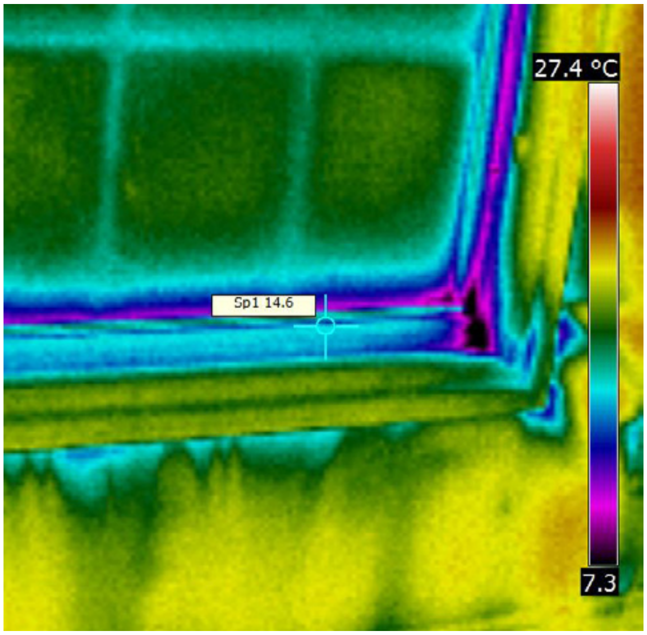
Figure 13. Infrared imagery showing leakage around window



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 in order 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]

- **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.

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)

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

- **Upgrade windows and doors:**

  Windows

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

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

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

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

Window selection

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

- **Minimize heat loss** by selecting the lowest U-value (highest RSI-value) for the entire assembly.
- **Minimize window emissivity** by selecting windows with low emissivity (low-e) in order to minimize heat radiated through the window.
- **Control solar heat gain.** The solar heat gain coefficient (SHGC) can differ depending on orientation to allow beneficial solar gains from one side (e.g. a south-facing wall with an SHGC of 0.6), while limiting solar gains on other sides (e.g. east- and west-facing walls with SHGCs of 0.25) for occupant comfort during the early and later parts of the day.
- **Maximize visible light transmittance**, T_{VIS}, for daylighting.[30]

The text box on page 28 provides a more detailed discussion of each of these criteria, along with a discussion of various window components and assemblies.

[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}.

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.

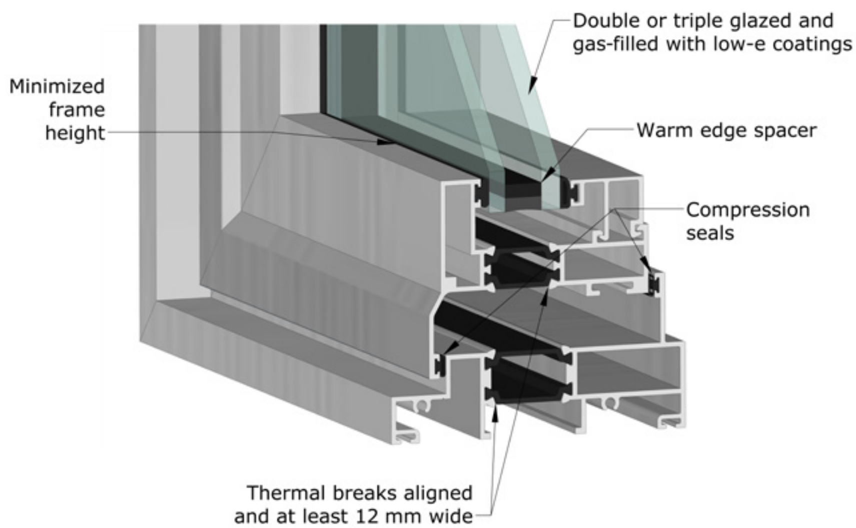
IGU performance is determined by:

- 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

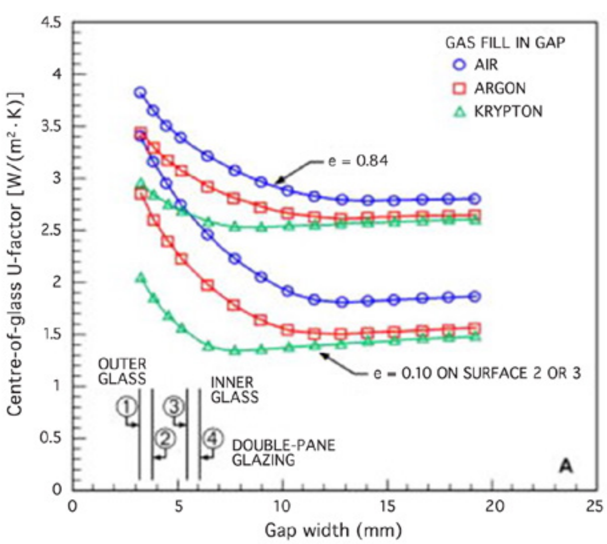
A window's U-factor incorporates the thermal properties of both the frame and the glazing. Since the sash and frame represent approximately 10 to 30% of the total area of the window unit, the frame's properties significantly influence the total window performance.

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.

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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**.
- **Add a vestibule:** The NECB 2011 prescriptive path requires new buildings to be designed with vestibules and self-closing devices for all regular access doors. Since the energy saving and comfort benefits are applicable to existing buildings, vestibules should be added where feasible.

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.

Some food store environments have 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. Food stores can have extremely high latent loads compared to their sensible loads and therefore sometimes 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%.

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.

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In addition to dedicated dehumidification equipment, rooftop units (RTUs) are the main type of system used to distribute and condition air in food stores. 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.[31]

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.

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.

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,[32] 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.

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

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

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Air distribution systems measure list
✓ Start with first-order measures
✓ Use demand control ventilation
✓ Install high-induction swirl diffusers
✓ 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.

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

  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.

  Typically, food stores only need to ventilate the retail space for regular occupants, and, consequently, a single CO_2 sensor per RTU is usually adequate to control ventilation properly. Economizer controls should always override DCV in control sequences.

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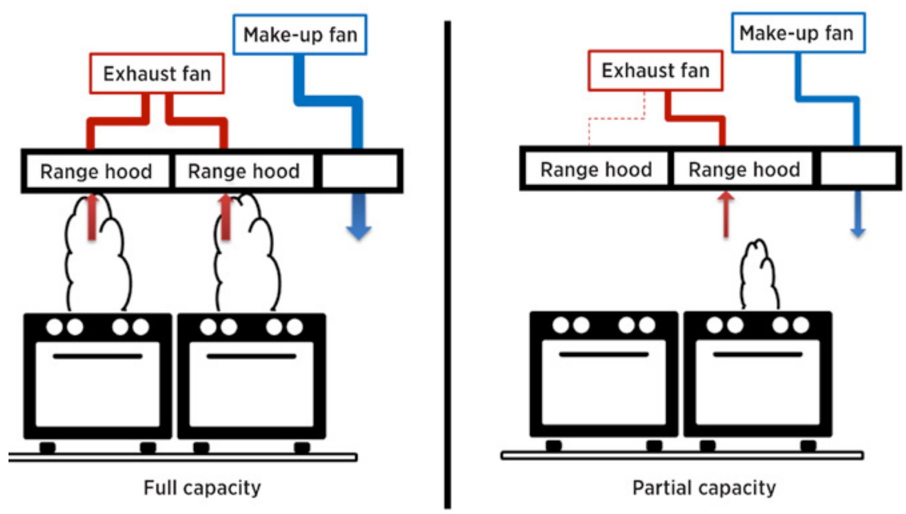
Kitchen hood exhaust

DCV can also be applied in food store 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 food store 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.[33]

Figure 16. Demand control kitchen ventilation



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

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

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

- **Eliminate heating in front entrance vestibule:** Many food stores 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.[34]

- **Replace direct expansion dehumidification with desiccant:** Conventional 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 food and beverage refrigeration systems, RTUs, as well as domestic hot water systems.

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

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

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Figure 17. Low temperature display case

Refrigeration systems

In food stores that sell cold food and beverage products, refrigeration systems are a significant end use, consuming over 20% of the facility'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.

Unlike other retail environments where temperature control is the sole focus, some food stores require an emphasis on humidification control. Extensive research in the area of food and beverage store 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 down 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 an example upgrade scenario.

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 food store 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.[35] Many studies have also shown that closed display cases do not negatively affect sales.

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

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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.

Figure 18. Medium-temperature display case with doors

Source: Arborus Consulting

- **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.[36]
- **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.

Case in Point:
M&M Meat Shops

Switching to LED lighting in the vertical display cases of about 150 stores has saved M&M Meat Shops more than $200,000 a year in energy and maintenance costs. It expects savings to triple once all franchisees replace the T10 fluorescent lighting with new LEDs. Each franchisee stands to save up to $1,400 a year in lower costs.

"You can see such a difference with these lights," said Dianne Chalmers, Senior Manager, Construction, M&M Meat Shops. "Some stores look 20 years younger."

Source: GE Lighting, **http://www.gelighting.com/LightingWeb/na/images/60856-GE-M-and-M-Meat-Shops-Case-Study_tcm201-44147.pdf**

[36] Ibid.

- **Use demand defrost control:** Although timing-initiated, temperature-termination controls with 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.[37] 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.

- **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 41). To eliminate the noise and cooling inefficiency, the equipment should be retrofitted with remote compressors and integrated with the store's central refrigeration system, if one exists.

- **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.[38] For comparative purposes, a 1.2-m fluorescent fixture consumes 32 W, while the equivalent LED consumes 15 W, a 52% saving.

Figure 19. Display case with LED lighting

Source: Arborus Consulting

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

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

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- **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 control 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

Figure 20. 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.

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- **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.

Free cooling

Ottawa-based Quickie Convenience Stores piloted a free cooling system that took advantage of outside air during the winter months to keep their refrigerated units cool. The system reduced electricity costs by 80% over the pilot period.

Source: Save on Energy, https://hydroottawa.com/media/news-releases?nid=40

- **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.
- **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.[39]
- **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.

[39] www.oesolutions.net.

- **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.[40] 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

- **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.

The **Liquor Control Board of Ontario** (LCBO) reduced energy consumption by 11% between 2011 and 2015. By tracking and analyzing energy use across all stores, the LCBO was able to target improvements for greater overall energy reductions. Retrofit measures included enhanced insulation and sealing, building automation systems, free-air cold rooms that use ambient cold outdoor air for half the year, "dairy doors" on previously open coolers, and LED lighting retrofits.

Source: Liquor Control Board of Ontario, http://www.lcbo.com/content/lcbo/en/responsibility/sustainability/greener-buildings.html#.VedD6vlViko

Figure 21. Refrigeration compressor

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

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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 food stores across the country are ideal candidates for this energy-saving measure.[41]

- **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.

- **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 operation, resulting in substantial maintenance savings and prolonged compressor and fan motor lifetimes.

[41] For more information, see RSES Journal April 2014, EEVs Enabling Low Condensing Refrigeration, by Andre Patenaude.

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- **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

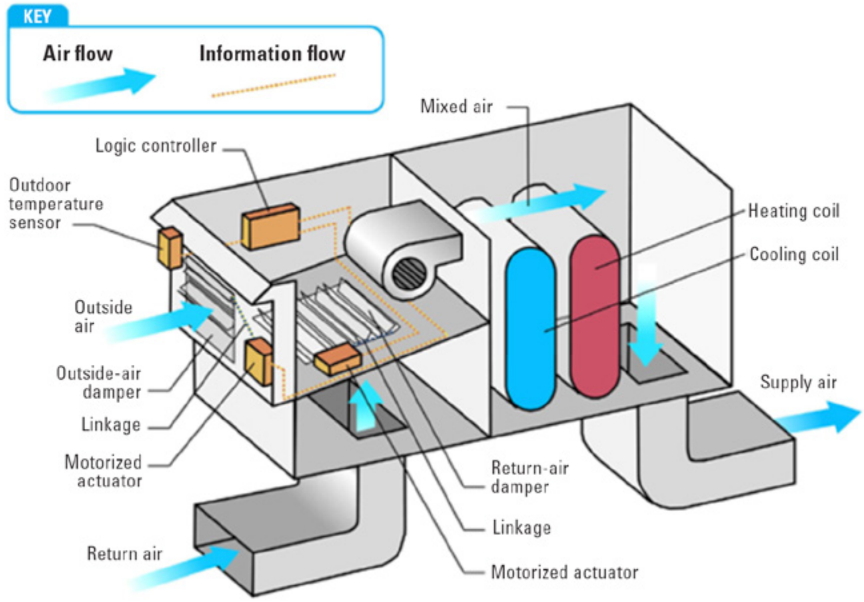
*Energy efficiency ratio

Rooftop units

More than a third of Canadian commercial/institutional building floor space—and the vast majority of Canadian food stores—is conditioned by self-contained, packaged rooftop units.[42] 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 22.

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

Figure 22. Typical RTU



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.

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.

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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

TThe 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.

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.

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

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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[43] provided independent analysis of this technology, with results showing a reduction in normalized annual RTU energy consumption between 22 and 90%, with an average of 57% for all RTUs.

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

[43] 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 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 re-circulated 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.

- **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

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.

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%.

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- 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 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.

Domestic hot water

Domestic water heating represents 7% of the energy used in Canadian food stores, 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:** Food store 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:** Food stores rarely have more than one washroom. 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,[44,45] and the savings are attributed to a lack of storage losses in conventional tank systems.

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

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.

[44] 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.

[45] 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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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

PART 2

COUCHE-TARD, QUEBEC: A CASE STUDY

Couche Tard operates more than 1,800 stores in Canada, offering convenience, restaurant and gas station services.

Couche-Tard, best known for its Couche-Tard®, Mac's® and Circle K® brands is one of the leaders in the North American convenience store industry. The company opened in 1980 with one store in Laval, Quebec; today, Couche-Tard is international, operating a network of almost 1,850 stores in Canada from coast to coast, more than 8,000 stores in total across North America, and about 2,200 stores in parts of Scandinavia and Eastern Europe. In addition, about 4,700 stores are operated by independent operators under the Circle K banner in 14 other countries or regions worldwide.

Like many food store chains, Couche-Tard faced several challenges when it came to improving energy performance, such as leased stores where a building owner may not want certain changes to be made, or the variety of equipment used in stores, depending on the services they provided. Access to capital was a particular challenge for Couche-Tard, as all financing decisions were made at the corporate level; with so many stores in its portfolio, it was often difficult to make the business case for discrete retrofits due to their long payback.

Beginning more than a decade ago, however, Couche-Tard decided to embrace energy efficiency as a way to cut costs, reduce its environmental impact, and enhance the customer experience with more brightly lit sites. It increased its efforts in 2010 when it launched a full energy management program.

Major benefits

- ✓ Between 2012 and 2015, Couche-Tard cut its overall North American electrical consumption by 11.4%.
- ✓ The average retrofit per store cost tens of thousands of dollars and generated annual energy savings between 5 and 10%.
- ✓ Since 2010, electricity consumption has been reduced by more than 1 billion kWh, roughly equivalent to the electricity use of more than 90,000 households.
- ✓ Couche-Tard's annual energy reduction target (currently 3%) is supported by a company-wide energy management program.

Figure 23: Couche-Tard convenience store

A typical Couche-Tard convenience store averages more than 150,000 kWh of electricity per year.

Photo courtesy of Couche-Tard.

PART 2

Getting informed

In 2004, Couche-Tard hired an energy services company (TST Energy) to conduct energy audits at five of its stores.

Janick Hardy, Energy Efficiency Project Manager with Couche-Tard, explained that, although many of Couche-Tard's Quebec stores are leased, the company is responsible for all of the energy bills and, after payroll, energy is one of the biggest expenses. The goal of the audits, therefore, was to find ways to reduce energy consumption in three specific areas: lighting, refrigeration and HVAC.

The audits provided the baseline information that the company needed to identify the stores with the greatest retrofit potential, including the type of equipment they used and what additional amenities they offered, such as a restaurant, a gas station, or both.

"We tested many different LED products and investigated many companies as we were starting energy upgrades," said Hardy. She pointed out, however, that at the time, LED products were much more expensive, and the calculated payback was more than 10 years.

Robert Cummins, co-founder and CEO of TST Energy explained that Couche-Tard is a decentralized organization with several different types of stores across many jurisdictions. "It was difficult to organize retrofit projects because of that," he said, adding that it also took time for the company to come to a consensus on which products to use, which stores to retrofit and how the upgrades would be financed.

Although certain stores were implementing some measures, ultimately Couche-Tard realized that it could take advantage of economies of scale and obtain better paybacks if all retrofit decisions were made through the national office.

It's also important to note that in 2004 the small size of Couche-Tard's stores and their relatively low levels of energy consumption made them ineligible for Hydro-Québec rebate programs. At the time, Hydro-Québec did not allow companies to apply on the basis of multiple sites. Couche-Tard took part in a focus group with Hydro-Québec and highlighted the fact that the utility was missing out on opportunities to reduce electricity use by not allowing sites to be aggregated under a single application. Couche-Tard's total annual energy costs for all its Quebec stores was roughly $10 million. "With that information, the idea of reducing a few energy percentage points suddenly became very interesting to them," said Cummins. Due in part to Couche-Tard's efforts, Hydro-Québec changed its application process to allow organizations with multiple smaller sites to be eligible under their programs.

With this more centralized focus, Couche-Tard partnered with Ecova, an energy and sustainability management company, in 2010. At that time, the focus was on managing the company's energy bills and reporting on energy consumption.

A year later, Couche-Tard launched its One-Touch energy program, which includes capital investments for retrofits and employee awareness initiatives, and is overseen by a corporate energy team. The team meets regularly to share best practices and consists of representatives from all divisions throughout Canada, the United States and Europe. Each division is provided with an annual energy saving budget.

The retrofits

Before committing capital for a retrofit, Couche-Tard considers a number of criteria, including the government or utility rebate or incentive programs available, the type of building systems and operating equipment used, the return on investment, and end-lease dates.

Lighting

LED exterior lighting has provided one of the greatest returns on investment (ROI) of all of Couche-Tard's retrofit measures, averaging between 1.5 to 3.0 years. More than 250 Couche-Tard stores in Quebec have had their indoor or outdoor lighting switched to LEDs (signage, ceiling lights, walk-in coolers, gas canopies, perimeter lighting, and car wash lighting). Exterior lighting is controlled by photocell, which ensures that lights are switched on only when required. Motion-activated sensors are installed in washrooms and utility rooms to reduce electrical consumption even more.

Refrigeration

Two-speed evaporator fans with electronically commutated motors (ECMs) have been installed on refrigeration equipment in more than 100 stores. ECMs can achieve full-load efficiencies of greater than 70%, compared to the 25 to 50% full-load efficiency of standard motors.

HVAC

Couche-Tard tested and installed HVAC control systems such as programmable thermostats and motion sensors for rear doors at about 50 of its stores.

Employee Programs

Couche-Tard partners with Ecova to publish a quarterly newsletter that shares stories about corporate initiatives and best practices and includes progress reports on energy and greenhouse gas reductions. "The success of energy reduction happens largely in the operations," said Hardy. "So it helps to pass on good practices and ensure that everyone is working in the same direction."

Typical Energy Breakdown by Store

Indoor/Outdoor Lighting	30%
Refrigeration	30%
HVAC	20%
Plug loads/ supplemental loads	20%

Figure 24: Interior lighting

Interior lighting was upgraded to LED in more than 130 Couche-Tard stores.

Photo courtesy of Couche-Tard.

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Financing

On average, each store retrofit has cost tens of thousands of dollars, depending on the measures used, and energy savings per store have averaged between 5 and 10%. Couche-Tard's target ROI is four years or less.

Information on the company's current capital investments is confidential; however, in fiscal 2011, the first year of the One-Touch program, Couche-Tard invested $5 million upgrading exterior fuel canopy and perimeter lighting to LED fixtures.

Through Couche-Tard's partnership with Ecova, incentive funds were secured through local utility program offerings to help offset the cost of these improvements. Incentives were secured for nearly 15% of the total projects' costs and, combined with the energy savings from the comprehensive approach, the simple payback of the retrofit projects is typically less than five years.

"With the One-Touch program, we combine all measures for each store and make the changes all at the same time," reported Hardy. By planning its retrofits this way, Hardy added, Couche-Tard saves money by contracting all trades to come in at the same time to perform the upgrades.

Monitoring

Ecova monitors energy data at all of Couche-Tard's North American stores, pays the energy bills on behalf of the company, and leverages its employees' talents and insights to recommend resource consumption opportunities that ultimately drive down Couche-Tard's costs.

Couche-Tard does not currently benchmark store performance against others in the food store industry, but does compare the energy consumption between its Quebec stores.

Hardy explained that monthly energy performance reports (EPRs) provided by Ecova enable them to compare increases or decreases in energy consumption per square metre for every store. The EPRs analyze consumption and cost data; Ecova's energy outlier investigation reports use EPR data to identify any stores that are deviating from the average in terms of energy and water use, and waste management.

"Each year, we set a reduction target and that is closely monitored throughout the year," said Hardy. "The monthly reports allow us to see if we are heading in the right direction and make any necessary corrections."

In addition, three stores in Quebec were outfitted with a sub-metering system that monitored energy use and performance of every circuit breaker. The data allowed Couche-Tard to try different energy saving measures to see which were more effective, track the overall performance of the stores, and make any necessary improvements or corrections.

Lessons learned

Hardy said that planning, monitoring, and understanding the progress of technology are among the most important considerations she makes before deciding on an energy savings project. However, the greatest challenge is in building the business case. "All of our energy saving projects must meet specific quality criteria," she said. "The return on investment remains the biggest challenge."

"[In our Quebec stores] we completed the easily attainable measures first," said Hardy. Although the company now has a retrofit decision process in place with its One-Touch program, the challenge ahead, Hardy said, is how to finance more expensive or complicated retrofit measures (with potentially longer paybacks) in a province where electricity costs remain relatively low.

That being said, Couche-Tard has made strategic use of the available rebate and incentive programs offered not only in Quebec but in many other jurisdictions where the company operates. Ecova and TST monitor these programs on the company's behalf and file grant applications for retrofits that meet the criteria. Without the type of funding offered by these various entities, such as Hydro-Québec, Hardy said, many of the projects Couche-Tard has done would have been more challenging.

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, 500-m^2 food store. 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**[46] estimates, marginal utility rate data was sourced from the three cities above.[47] 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.

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

[47] 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 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 and fluorescent 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	150.6	$35,610	$1,370	-$5,364	2.8%	26.0
Edmonton	197.6	$36,839	$1,369	-$6,620	2.6%	26.9
Montreal	180.3	$35,678	$1,971	$7,830	5.5%	18.1

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	44.4	$5,052	$512	$6,260	11.4%	9.9
Edmonton	36.4	$5,134	$244	$258	4.4%	21.0
Montreal	23.9	$4,919	$262	$867	5.2%	18.8

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	8.6	$5,621	$75	-$3,964	-3.3%	74.9
Edmonton	13.2	$5,672	$80	-$3,915	-3.1%	71.3
Montreal	12.1	$5,411	$130	-$2,544	-0.2%	41.7

Measure-specific assumptions and notes:

- Window U-value upgraded from 3.5-W/m^2·K (0.62 Btu/hr-sq. ft. ·oF) to 2.0-W/m^2·K (0.35 Btu/hr-sq. ft. ·oF)

Heating and cooling resizing and replacement

Walk-in coolers and display cases (controls & free cooling)

Example City	Annual Savings Estimate (GJ)	Full Cost Estimate	Annual Energy Cost Savings	NPV Estimate	IRR Estimate	Simple Payback (yrs)
Vancouver	140.2	$24,039	$3,856	$24,673	15.6%	6.2
Edmonton	165.9	$24,039	$3,724	$23,005	14.9%	6.5
Montreal	160.7	$24,039	$2,736	$10,533	9.4%	8.8

Measure-specific assumptions and notes:

- Equipment: one walk-in cooler, plus five medium-temperature display cases
- Retrofit case: free cooling, ECM evaporator motors, LED lighting, anti-sweat heater control (store environment @55%RH)

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	99.7	$45,932	$812	-$35,668	-11.7%	56.5
Edmonton	177.3	$45,932	$1,129	-$31,664	-8.9%	40.7
Montreal	191.0	$45,932	$2,003	-$20,626	-3.2%	22.9

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
- 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 $66,410

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	90.1	$8,320	$1,230	$7,217	14.0%	6.8
Edmonton	163.1	$8,320	$1,441	$9,882	17.1%	5.8
Montreal	165.6	$8,320	$1,847	$15,017	22.8%	4.5

Measure-specific assumptions and notes:

- Equipment: 35-kW (10-ton) rooftop air handling unit
- 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 $28,798

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: ____________

Food Stores – Opportunity Questionnaire

EBCx

- ❑ Do the lighting and occupancy schedules match? [Pg. 9]
- ❑ Is the air handling system on a schedule? [Pg. 9]
- ❑ Are the zone temperature set points set back/forward during unoccupied hours? [Pg. 9]
- ❑ Does the RTU have a properly functioning economizer to enable free cooling? [Pg. 10]
- ❑ Is the supply air temperature reset depending on outdoor conditions? [Pg. 10]
- ❑ Has humidity control been calibrated? [Pg. 10]
- ❑ Are fan belts and pulleys operating at proper tension? [Pg. 10]

Lighting upgrades

Interior

- ○ Have existing fixtures or lamps been replaced with LED lamps? [Pg. 18]
- ○ Have incandescent Exit signs been replaced with LED signs? [Pg. 19]
- ○ Have wall switches in enclosed rooms been replaced with occupancy/vacancy sensors? [Pg. 19]
- ◇ Have daylight sources and lighting control been installed? [Pg. 19]

Exterior / parking lot

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

Supplemental load reduction

Power loads and equipment

- ○ Is equipment being turned off when not in use? [Pg. 21]
- ○ Is ENERGY STAR equipment being used where applicable? [Pg. 21]
- ○ Have vending machine controls been added? [Pg. 21]
- ○ Has an employee energy awareness program been implemented? [Pg. 23]
- ◇ Has kitchen equipment been replaced with efficient fixtures and appliances? [Pg. 22]

Envelope

- ○ Have infiltration issues been addressed? [Pg. 24]
- ◇ Has an air barrier been added or improved? [Pg. 25]
- ◇ Do roof and wall insulation levels meet NECB requirements? [Pg. 26]
- ◇ Have the windows and doors been upgraded? [Pg. 27]

Air distribution systems upgrade

- ○ Have high-induction swirl diffusers been installed in retail areas? [Pg. 35]
- ○ Has heating been eliminated from front entrance vestibules? [Pg. 35]
- ◇ Is there a DCV system? [Pg. 33]
- ◇ Has DX dehumidification been replaced with desiccant? [Pg. 35]

Heating and cooling resizing and replacement

Rooftop units

- ○ Is an early morning flush performed regularly during the cooling season? [Pg. 47]
- ○ Are the outside air dampers closed during morning warm-up during the heating season? [Pg. 47]
- ◇ Has the CV system been converted to a variable flow system with demand control and an economizer? [Pg. 46]
- ◇ Have compressor controllers been installed on the RTU to reduce runtime? [Pg. 46]
- ◇ Has an economizer damper been added? [Pg. 47]
- ◇ Have old RTUs been replaced with new high-efficiency units? [Pg. 47]

- ❑ Have the BAS sensors been calibrated recently? [Pg. 11]
- ❑ Have supply and exhaust air imbalances been corrected? [Pg. 11]
- ❑ Has missing or damaged pipe insulation been repaired? [Pg. 11]
- ❑ Is the ductwork sealed to prevent leakage? [Pg. 11]
- ❑ Have refrigeration leaks been investigated and corrected? [Pg. 11]
- ❑ Have display case temperature controls been checked and adjusted? [Pg. 11]
- ❑ Has the defrost cycle been optimized? [Pg. 12]

Refrigeration System Measures

Display Cases

- ❍ Are night curtains beng used on open medium-temperature cases during unoccupied hours? [Pg. 37]
- ❍ Are anti-sweat heaters controlled to cycle based on dew point? [Pg. 37]
- ❍ Has lighting been replaced with LED lamps? [Pg. 38]
- ◇ Have doors been installed on medium-temperature cases? [Pg. 36]
- ◇ Is demand defrost control being used? [Pg. 38]
- ◇ Have compressors been centralized and located away from retail areas? [Pg. 38]
- ◇ Have evaporator fan motors been replaced with ECMs? [Pg. 39]

Walk-In Coolers and Freezers

- ❍ Are fans turned off while doors are open? [Pg. 39]
- ❍ Have strip curtains been installed? [Pg. 40]
- ❍ Are compressors turned off while doors are open? [Pg. 40]
- ❍ Have closures been added to doors [Pg. 41]
- ❍ Is air defrost being leveraged for medium-temperature coolers? [Pg. 41]
- ❍ Has lighting been replaced with LED lamps? [Pg. 41]
- ◇ Has insulation been upgraded? [Pg. 39]
- ◇ Are advanced electric defrost controls being used for low-temperature freezers? [Pg. 40]
- ◇ Have two-speed evaporator fans been installed? [Pg. 40x0]
- ◇ Have evaporator fan motors been replaced with ECMs? [Pg. 40]
- ◇ Has a free cooling system been installed? [Pg. 40]

Compressor Systems

- ◇ Is heat being recovered from the condensing circuit? [Pg. 41]
- ◇ Has floating head pressure been reduced? [Pg. 42]
- ◇ Have EEVs been installed? [Pg. 42]
- ◇ Has the condenser system been converted into a hybrid system? [Pg. 41]
- ◇ Have variable speed fans been installed on low-temperature condensers? [Pg. 42]
- ◇ Has ambient refrigeration subcooling been added to condenser circuits? [Pg. 43]
- ◇ Have compressors been replaced with new digital equipment and controls? [Pg. 43]

Domestic hot water

- ❍ Have low-flow aerators and showerheads been installed? [Pg. 48]
- ◇ Is water being preheated with heat recovery from the refrigeration circuit? [Pg. 48]
- ◇ Has the hot water heater been replaced with a high-efficiency unit? [Pg. 49]
- ◇ Have storage-based hot water systems been replaced with tankless? [Pg. 49]