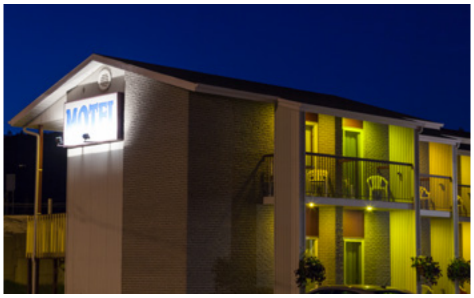
Natural Resources Canada
Ressources naturelles Canada

Major Energy Retrofit Guidelines

for Commercial and Institutional Buildings



HOTELS AND MOTELS

Canada

Natural Resources
Canada

Ressources naturelles
Canada

Major Energy Retrofit Guidelines

for Commercial and Institutional Buildings

HOTELS AND MOTELS

Canada

Aussi disponible en français sous le titre : Directives sur les réaménagements énergétiques majeurs – Module sur les hôtels et motels

This report is available online at **nrcan.gc.ca/energy/efficiency/buildings/eeeb/retrofit/4111**.

Cat. No. M144-268/1-2018E-PDF
ISSN 978-0-660-24749-6

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

ACKNOWLEDGEMENTS

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

DISCLAIMER

CONTENTS

Figures

Tables

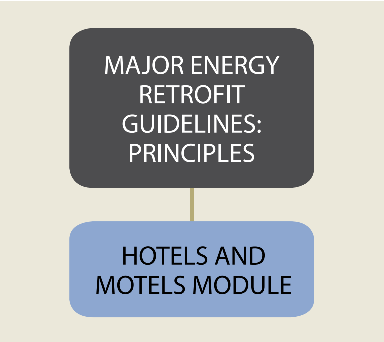
PART 1

RETROFIT OPPORTUNITIES IN HOTELS AND MOTELS

The Hotels and Motels 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 hotels and motels.

The Hotels and Motels Module is divided into four parts:

1. **Retrofit Opportunities in Hotels and Motels:** Provides an overview of Canadian hotels and motels. Subsections present background information on each retrofit stage and key retrofit measures, with a focus on small and medium-sized hotels and motels. On the whole, these measures target hotel facilities; however, some or all of these measures are also applicable to motels depending on the amenities available and nature of the central building systems present.
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.



Hotels and motels include properties renting temporary accommodations, such as a suite or room, on a nightly or short-term basis. These properties typically have daily services available to guests, including housekeeping or laundry and a front desk or concierge. The floor area includes all interior space, including guest rooms, lobbies, atriums, food preparation and restaurant space, conference and banquet space, health clubs or spas, indoor pool areas and laundry facilities. Additionally, spaces include supporting functions such as mechanical rooms, storage areas, employee break rooms and back offices.

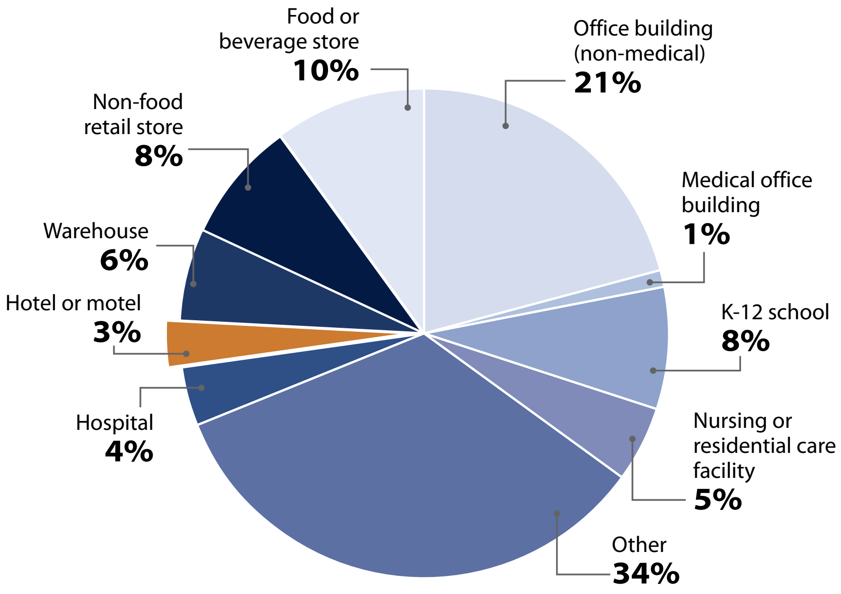
PART 1

Hotels and motels overview

Call to action

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

Figure 1. Commercial/institutional energy use by subsector



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

Figure 1 shows that within the commercial and institutional buildings sector, hotels and motels account for three percent of energy use.

Hotel and motel business owners know that guest experience is paramount. In recent years, hotels owners have also acknowledged the importance of sustainability and have been promoting the green initiatives undertaken at their hotels to their guests.

---

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

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

Luckily there are many ways to improve guest experience at your property, while also addressing energy efficiency. For example, because first impressions are often made when guests arrive at reception, lighting in these spaces is as much about setting a mood as it is about serving a technical function. As outlined later in this module, recent advancements in lighting technology have been instrumental in achieving high quality lighting environments, while at the same time lowering energy consumption.

Another example of a building system that can be retrofitted to improve guest experience while lowering energy use (or consumption), is the packaged terminal air conditioning units (PTACs) used to heat and cool air in guest rooms. This module presents a number of options to improve the performance of these systems while also enhancing guest comfort.

The varied nature of the physical facilities and amenities of hotels and motels make this sector unique. For example, hotels are made up of spaces that are occupied 24 hours a day, seven days a week, as well as spaces that have scheduled occupancies, such as offices and meeting facilities. On-site laundry facilities, commercial kitchens, fitness rooms, meeting/conference rooms and swimming pools are also common within the full range of motels and hotels. The good news is that this variety and the need to operate major systems around the clock mean that energy savings opportunities are abundant.[3]

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 guests and employees, to improve facility performance and financial returns, to cut energy costs, and to demonstrate their commitment to sustainability.

There are numerous reasons why you may be initiating a major energy retrofit in your facility. You may be experiencing increasing temperature complaints from guests due to equipment control problems, or you may have malfunctioning equipment as a result of deferred maintenance. Major capital equipment or building infrastructure, such as your roof, may be overdue for replacement. Major changes in the way spaces are used, or modernization changes to update branding, may also trigger an energy retrofit.

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

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

---

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

PART 1

Opportunities

Energy savings are one of the principal benefits of a major retrofit project. Savings from improved operational efficiency lead to increased revenue without impacting business activities. Additionally, lowering operating costs can allow funds to be deployed to upgrade amenities, or to improve the interior and exterior appearance of your hotel or motel. 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 an improved corporate image. Improved guest comfort and increasing guest awareness about your organization's energy efficiency efforts can enhance your reputation and help to increase occupancy rates in a highly competitive industry.

Challenges

Major energy retrofits in hotel and motel facilities can face several challenges:

- Scheduling constraints: Hotels and motels typically operate continuously, 365 days per year. This means owners and property managers must consider disruption to guests and the potential impact on hotel occupancy when undertaking a major retrofit project. Depending on the retrofit activities and the spaces affected, sections of the hotel may need to be closed off for a period of time.[4]
- Access to capital funding: Another barrier to achieving energy efficiency in hotels and motels is securing capital for project implementation. Within the industry, cosmetic upgrades tend to be favoured over mechanical upgrades. Also, in hotel franchises where equipment and building infrastructure related decisions are made at the corporate headquarters level, financing for building upgrades must compete with funding allocated for new construction. For example, decision makers at the corporate level often look for payback periods of two years or less on projects in existing buildings, largely because the funds needed for these projects compete with the capital required for opening new hotels.[5]
- Incomplete asset management plans: Many independently-owned hotels and motels do not have comprehensive asset management plans. Since building equipment and infrastructure are typically replaced or renewed only upon failure, it is important for building owners to determine which components need to be replaced and when the replacements should be scheduled so that an energy efficiency strategy can be developed. For more information on asset management planning, see Section 2 of the Principles Module.

---

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

[5] Ibid.

Energy use profile

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

Figure 2. Energy use by energy source

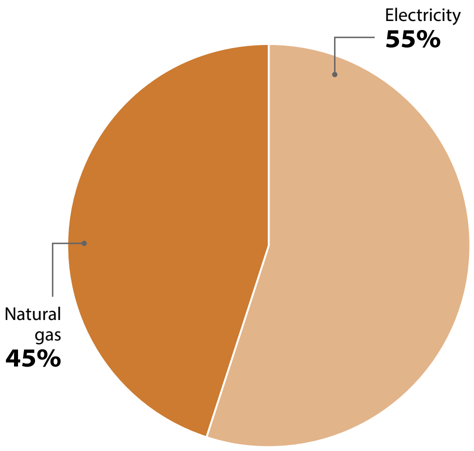
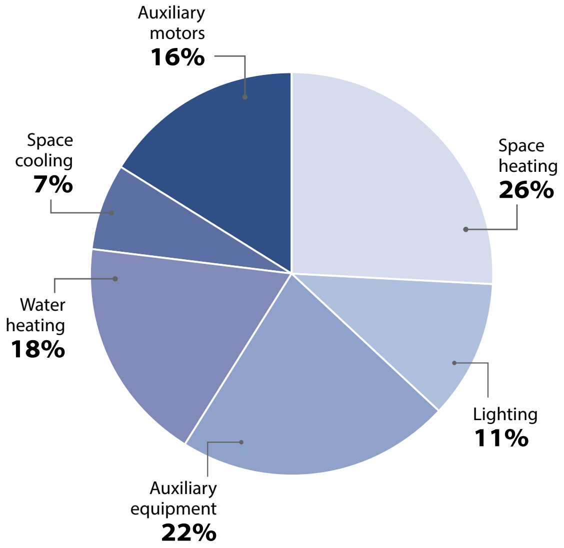


Figure 3. Energy use by end use



Data source: NRCan's Existing Buildings Initiative and ecoEnergy

Figure 2 shows the breakdown of consumption by energy source. Natural gas and electricity provide approximately equal shares of a typical hotel or motel's energy requirements. Figure 3 shows the breakdown of consumption by end use. Space heating is the largest end use, followed by auxiliary equipment (e.g. televisions, hairdryers, computers and electronics, laundry and food service equipment) and water heating.

The national median site energy use intensity for hotels and motels in Canada is 1.37 GJ per square metre.[6] That is, half of Canadian hotels and motels consume more than 1.37 GJ per square metre, while half use less. While the median site energy use intensity can be a useful metric for comparison purposes, it should be noted that energy intensity in hotels and motels can vary widely. This variation is influenced by weather conditions and specific facility and operating characteristics such as number of guest rooms, number of employees, presence of on-site commercial food preparation, number of commercial refrigeration units, and percentage of the facility's space that is heated and cooled.

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

---

[6] ENERGY STAR Portfolio Manager 2018. Technical reference: *Canadian Energy Use Intensity by Property Type.*

PART 1

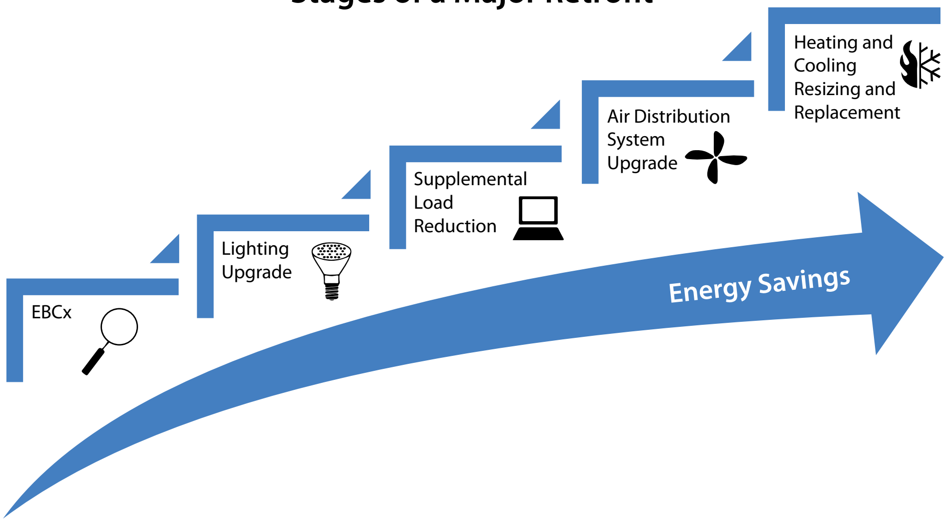
Hotel and motel managers are encouraged to benchmark and track their energy performance using ENERGY STAR Portfolio Manager, the most comprehensive and only standardized energy benchmarking tool in Canada. Benchmarking allows you to compare your current energy use against past performance as well as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

Staging project measures

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

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.

Stages of a Major Retrofit



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

Existing building commissioning

Commissioning is a first-order activity to improve an existing building's energy performance. Field results have shown that proper existing building commissioning (EBCx) can achieve energy savings ranging from 5 to 20%, with a typical payback period 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 incrGease revenue through improved building operations.

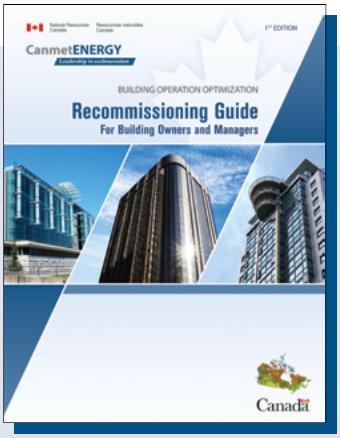
In Section 1 of the Principles Module, we explained how an EBCx program has four phases: assessment, investigation, implementation and hand-off.

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 following measures represent some of the typical improvements made under EBCx. It is important that all measures be implemented with suitable commissioning to ensure that system retrofits are optimized.[9]

Hotels are made up of spaces that are occupied 24 hours a day, seven days a week, as well as spaces that have scheduled occupancies, such as offices and meeting rooms. The EBCx measures listed below that address scheduling and setback temperatures only apply to areas within the facility where equipment and lighting can be turned off during unoccupied periods.



CanmetENERGY

BUILDING OPERATION OPTIMIZATION

Recommissioning Guide

For Building Owners and Managers

Canada

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.

EBCx measure list

- ✓ Confirm lighting control schedule
- ✓ Schedule air handling system
- ✓ Employ temperature setback during unoccupied hours
- ✓ Verify free cooling operation (air side)
- ✓ Widen zone temperature deadband
- ✓ Reset supply air temperature
- ✓ Correct damper operation
- ✓ Correct over-ventilation
- ✓ Correct imbalances between supply air and exhaust
- ✓ Verify humidification set point
- ✓ Lower variable air volume box minimum flow set points
- ✓ Repair missing or damaged duct insulation
- ✓ Investigate and address sealing around packaged terminal air conditioning units
- ✓ Repair missing or damaged pipe insulation
- ✓ Seal ductwork to prevent leakage
- ✓ Check fan belts and pulleys for tension and wear
- ✓ Reset boiler supply temperature
- ✓ Calibrate building automation system sensors
- ✓ Clean packaged terminal air conditioning unit coils

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

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

- **Employ temperature setback during unoccupied hours:** One of the most cost effective means of reducing energy consumption is by modifying the temperature set point of a space when it is empty, i.e. letting the thermostat setting 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 guests or staff arrive. Review the set points for heating and cooling during unoccupied hours to ensure that setback temperatures are in place.

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

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

- **Widen zone temperature deadband:** Zone temperature deadband is the temperature range in which neither heating nor cooling is provided to the zone. By widening the zone temperature deadband, unnecessary "fighting" between heating and cooling systems is prevented, and energy consumption is minimized. This also mitigates heating and cooling system instability caused by short-term cycling between heating and cooling modes.

- **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.

---

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

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

- **Correct damper operation:** For systems with zone dampers (variable air volume [VAV]), periodically inspect the dampers, linkages and actuators for proper operation. In older buildings, where maintenance has not been rigorous, some zone dampers may be stuck in a fixed position, rendering them ineffective at regulating comfort.
- **Correct over-ventilation:** Measure air flows against ASHRAE Standard 62[12] calculations to ensure that the system meets the minimum ventilation rates but does not result in increased energy consumption due to over-ventilation. To match ventilation rates according to varying occupancy rates, a demand control regime can be implemented whereby CO_2 sensors provide feedback to the HVAC system's outdoor air damper control to modulate the damper's position according to the occupant load in the space served by the system. This strategy is especially beneficial for spaces with highly variable occupancies (e.g. meeting or assembly spaces) because it allows the outdoor air to be closed off during unoccupied periods, saving the portion of energy needed to condition outdoor air.
- **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.
- **Verify humidification set point:** Verify that the humidification set point meets, but does not exceed, the minimal relative humidity requirements of ASHRAE 55.
- **Lower variable air volume box minimum flow set points:** VAV box manufacturers typically list a minimum recommended air flow set point for each box size and for each standard control option. However, when direct digital control (DDC) is employed, the actual controllable minimum set point will depend on the specific requirements of the space involved and is usually much lower than the manufacturer's scheduled minimum. Reducing the minimum set point will result in lower fan power requirements.
- **Repair missing or damaged duct insulation:** Routine inspections of duct insulation can identify areas that require repair. Without insulation, conditioned air in the duct will warm or cool unconditioned spaces, such as ceiling plenums, before it reaches the intended zone.
- **Investigate and address sealing around packaged terminal air conditioning units:** PTACs are mounted through the exterior wall and therefore must be sealed against water entry and air leakage. Gaps may occur as a result of improper installation or deterioration of the sealant. Sealing the gaps is critical to maintaining occupant comfort, protecting the building elements and reducing the energy impacts due to infiltration.

---

[12] *ANSI/ASHRAE Standard 62.1-2013 — Ventilation for Acceptable Indoor Air Quality.* ASHRAE, 2013. ashrae.org/resources--publications/bookstore/standards-62-1--62-2.

- **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. Refer to the Central heating systems and Domestic hot water sections within the Heating and cooling resizing and replacement stage for more details.
- **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 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.
- **Check fan belts and pulleys for tension and wear:** Typical losses from belt-driven fans can be 2 to 6%.[13] 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.
- **Reset boiler supply temperature:** During the shoulder seasons, facility heating loads can often be met with lower heating water temperatures. Resetting the supply water temperature based on outdoor air temperature helps match boiler output to the actual load and results in energy savings.
- **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.
- **Clean packaged terminal air conditioning unit coils:** Over time, coils can collect dust and debris, and in some cases may collect bacteria and mold. Dirty coils will negatively impact the effectiveness of the coils and can cause undesirable smells from the supply air, resulting in an unpleasant guest experience. Coils should be cleaned every three years to prevent deterioration of performance and air quality.

Figure 4. HVAC pipe insulation

Photo courtesy of Claudette Poirier, Vancouver Island Health Authority

---

[13] Stamper, Koral. *Handbook of Air Conditioning, Heating and Ventilating.*

Lighting upgrades

Lighting consumes approximately 11% of the energy used in Canadian hotels and motels and affects other building systems through its electrical requirements and the waste heat it produces. Upgrading lighting systems with efficient light sources, fixtures and controls reduces lighting energy use, improves the visual environment and can impact the sizing of HVAC and electrical systems.

Lighting upgrades are often attractive investments with relatively low capital costs and short payback periods. Even simple upgrades can reduce lighting energy consumption between 10 and 85%[14] and have the potential to improve guest experience and employee health and satisfaction. If one considers that prescribed lighting power densities from older codes are at least double the power density prescribed in current codes, an energy saving potential of 50% is possible, even without additional controls.

Advancements in LED lighting technology have been instrumental in the design of new hotels, achieving high quality lighting environments while lowering electrical and demand charges.

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.

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

---

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

Table 1. Illuminance recommendations for hotels and motels

Application and task	Illuminance targets (lux)[15]
Lobby / reception	150[16]
Corridors	100
Dining room	100
Kitchen	500
Conference room	300
Pool (deck)	300

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

When designing lighting modifications, the following principles apply:

- Design lighting layouts in accordance with the principles of the Illuminating Engineering Society of North America (IESNA) standards.
- Ensure that lighting power density 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.

Hotel lighting characteristics are further discussed in the context of interior and exterior lighting.

Interior

The reception area acts as a hotel's business card. This is where hotel guests find their bearings and where they expect to find friendly staff and a feeling of security. A hotel room is a temporary home away from home for guests, and they want to feel welcome and able to relax. Lighting, therefore, is as much about setting a mood as it is about serving a technical function.

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.

---

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

[16] General lighting levels vary depending on the degree of accent lighting.

Reflectance of surfaces

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

Figure 5. Interior lighting – hotel lobby

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

Lighting power densities (LPDs) have decreased due to advancements in energy-efficient lighting systems. The 1997 *Model National Energy Code for Buildings* (MNECB) prescribed LPDs for hotels by space type. The NECB 2011 prescribes a maximum average building LPD for hotels of 10.8 W/m^2, as well as LPDs by space type:

Table 2. Maximum average building LPD

Space type	MNECB LPD (W/m^2)	NECB 2011 LPD (W/m^2)
Lobby	20.4	11.4
Casual dining	26.9	8.8
Guest rooms	15.1	11.9

Guide to calculating LPD

1. Identify boundaries in the area of study, measure and calculate the floor area in square metres.
2. Collect input power or amperage for each lighting fixture type in the area. This should be available on an electrical data label applied to fixtures. Do not use lamp wattages. Where input power is indicated in watts, use this value. Where input current is provided in amperes, multiply the amperage by the voltage (120 V, 208 V or 347 V) to obtain the wattage.
3. Calculate the sum of the fixture input wattages and divide by the area to determine LPD in watts per square metre.

High- and low-bay lighting technology

High-bay lighting in hotel environments has traditionally come in the form of high-intensity discharge (HID) metal halide (MH). However, in recent years, standard HID lighting has been replaced by fluorescent or the new ceramic MH; most recently, high- 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.[17]
- Fixture efficiency: This is a function of the fixture's design and its ability to project the available lumen output from the lamps. Most existing HID fixtures have an overall fixture efficiency between 60 and 70%. High-bay fluorescent fixtures have efficiencies greater than 90% due largely to the highly reflective qualities of the fixture reflectors and lack of diffusers. There is little data available on fixture efficiency for LED-based luminaires, since many fixture designs have direct output LEDs without reflectors or diffusers. In many cases the fixture efficiency (efficacy) is the same as the efficacy of the LED array.
- On-off cycling: Lamp life is influenced by the number and duration of on-off cycles. Lamp life is increased by lowering the frequency and increasing the duration of on-off cycles (i.e. turning the lights on and off fewer times over the course of the day). This is not a factor for LED technology.
- Colour: Colour rendering index (CRI) is a quantitative measure of the ability of a light source to reveal the colours of various objects correctly in comparison with an ideal or natural light source; the higher the number, the better the CRI. Metal halide CRI is 65, while high-output fluorescent CRI ranges from 80 to 85. For LED lighting, CRI can exceed 90, making it a good choice when colour accuracy is important. As noted previously, the LED industry is rapidly evolving, and more options for high CRI are being developed.
- Warm-up period and switching: Fluorescent lamps have a typical warm-up period of less than 1.5 seconds, while MH lamps have a warm-up period approaching 3 minutes. Similarly, fluorescent lamps will restrike (switching back on after being turned 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.

---

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

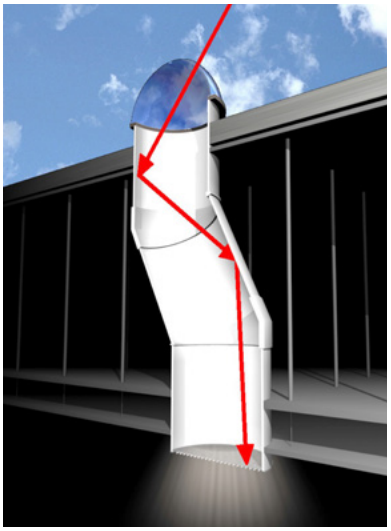
Light emitting diode (LED) lighting

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

Figure 6. Sealed dome skylight

Source: Wikimedia Commons

Figure 7. Light tube skylight



Source: P. Ellis, R. Strand and K. Baumgartner, Simulation of Tubular Daylighting Devices and Daylighting Shelves in EnergyPlus

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, and energy savings. Poor daylighting designs, however, result in glare and irregular luminance, and ultimately occupant dissatisfaction. When redesigning the lighting system, daylighting design should be the first step in the lighting design process. Electric lighting design should then be focused on complementing daylight during daytime and providing proper illumination on its own during nighttime. Lighting controls that respond to natural levels through dimming or switching should adjust electrical lighting levels gradually to provide a better environment for occupants.

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 solar gains through glazing are also factors to consider. Shading controls can reduce heat gains, and appropriate window glazing selection is necessary to reduce thermal loss through the glazing. Overall, a well-executed daylighting design will reduce cooling loads.
- *Reduced peak electricity demand.* 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 spaces 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
✓ Install suite occupancy controls

- **Replace existing light fixtures or lamps with LED lamps:** Replacement LED lamps and fixtures are available for a wide range of existing fixtures. Table 3 provides examples of replacements for fixtures common in hotels and motels.

Table 3. 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[18]	4658[19]	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 the lights on when occupancy is detected; vacancy sensors require manual activation of the wall switch to turn lights on. Vacancy sensors deliver the highest savings since the lights will never automatically turn on. A time-out period of 15 minutes is typical to avoid short cycling and reduced lamp life. The U.S. Environmental Protection Agency (EPA) estimates savings potential under optimal conditions ranging from 25 to 75% of lighting energy, depending on space type.[20]

In 2007, all of the Fairmont Winnipeg's lighting was replaced with energy-efficient options, reducing annual energy use by more than 880,000 kWh and saving about $44,000 a year.

Source: Fairmont Resorts & Hotels, fairmont.com/corporate-responsibility/environment/energy/hotel-initiatives/

---

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

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

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

- **Install daylight sources and lighting control:** A well-designed daylighting strategy with photosensor controls that dim or switch off fixtures when adequate daylight is available can save significant energy as well as maintenance costs.
- **Install suite occupancy controls:** Suite occupancy controls have become a common retrofit for hotels and motels. Infrared and acoustic sensors or key card switches provide the basis of occupancy detection to control lighting, receptacles and HVAC. Lighting is commonly left on when rooms are unoccupied, so providing occupancy sensing avoids this unnecessary energy consumption. See **Guest suite equipment** for a further discussion on suite energy management.

Exterior / parking lot

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

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

Lighting measure list (exterior / parking lot)

✓ Replace building exterior and parking lot lighting with LED lamps
✓ Add occupancy controls for parking garage lighting
✓ Replace parking garage lighting with LED lamps

- **Replace building exterior and parking lot lighting with LED lamps:** The exterior lighting of a building typically operates close to 12 hours a day, or approximately 4,300 hours per year. 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.

Figure 8. Hotel parking garage lighting

- **Add occupancy controls for parking garage lighting:** Lighting in enclosed parking garages is typically operated at full output 24 hours a day, seven days a week. However, since these spaces are often unoccupied, implementing bi-level occupancy-based controls can yield significant energy savings. With this strategy, lights operate at full power whenever the occupancy sensors detect activity and at a reduced level during periods of inactivity. Energy savings depend on use patterns by pedestrians and vehicles, but typically range from 20 to 80%.[21]

- **Replace parking garage lighting with LED lamps:** LED retrofits for parking garage lighting have become a common energy upgrade with attractive payback periods due to lower power density and constant operation. For example, replacing 175-W MH fixtures with LED lamps will result in nearly 50% savings, as shown in Table 4.

Figure 9. LED parking lot lighting

Table 4. Replacement examples for garage lighting fixtures

Existing fixtures			LED replacement		Demand savings
Type	Fixture wattage	Lumens	Fixture wattage	Lumens	%
175-W MH	208 W	7539	107 W	7141	49%

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

Supplemental load reduction

Supplemental load sources are secondary load contributors to energy consumption in buildings (occupants, equipment, building envelope components, 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.

---

[21] e3tnw.org/ItemDetail.aspx?id=63

Power loads and standard equipment

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

Supplemental load measure list (power loads and standard equipment)

- ✓ Power off equipment when not in use
- ✓ Install vending machine controls
- ✓ Choose ENERGY STAR equipment
- ✓ Install suite occupancy controls
- ✓ Implement an employee energy awareness program
- ✓ Install high-efficiency transformers

- **Power off equipment when not in use:** The first step in energy savings is turning off equipment and devices when they are not in use. For computers, monitors and point-of-sale terminals, power management settings can be set to automatically power off.

- **Install vending machine controls:** Vending machines are another example of equipment that can be powered down to save energy. Retrofit products are available that use motion sensors to turn machines off when spaces are unoccupied. The machines are powered back up when spaces are in use and at regular intervals to keep their contents cool. See the Business Case Guidance section for information on the costs and benefits of an example upgrade scenario.

- **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-qualified products such as computers, office equipment, lighting fixtures and lamps, kitchen equipment, and electronics. The Commercial kitchens section, below, provides further information on commercial kitchen equipment, including currently available ENERGY STAR-qualified equipment.

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

- **Install suite occupancy controls:** Occupancy sensing and plug load control has become the latest technological energy retrofit option. Suite occupancy controls can power off plug loads and lighting and implement setback temperatures for HVAC. See **Guest suite equipment** for further discussion on suite energy management.

- **Implement an employee energy awareness program:** NRCan's *Implementing an Energy Efficiency Awareness Program*[22] can help owners and managers develop successful employee energy awareness programs. Another useful resource is the *ENERGY STAR Guidelines for Energy Management*.[23] It provides information on creating a communications plan, and ideas, examples and templates that can be customized to help spread the word to employees, guests and other stakeholders.

  Programs focused on guest energy and sustainability awareness are common in the hotel industry and often involve notes left for guests in their rooms to encourage resource conservation (e.g. energy, water). Green Key Global, a graduated rating system designed to recognize green hotels and motels, provides a list of tips that guests can adopt while staying at your property.[24]

- **Install high-efficiency transformers:** Replace existing transformers at the end of their service life with high-efficiency transformers. In the past several years, there has been an accelerated rate of change to introduce energy efficiency standards for transformers in North America. As a result, manufacturers are offering more efficient transformers that have fewer losses than older models. The new National Electrical Manufacturers Association's (NEMA) premium efficiency transformer designations (CSA C802) require 30% fewer losses than previous regulations.

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

  Replacing a single 75-kVA transformer (98% efficient) with a NEMA premium-efficiency transformer (98.6% efficient) reduces the annual transformer losses by approximately 30%, based on 260 days/year, 15% loading for 16 hours/day and 100% loading for eight hours/day.[25]

---

[22] publications.gc.ca/collections/collection_2013/rncan-nrcan/M144-244-2012-eng.pdf

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

[24] greenkeyglobal.com/travel-green/

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

Commercial kitchen

A wide range of equipment, fixtures and appliances contribute to energy consumption in hotel and motel 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.

Figure 10. Hotel kitchen

Supplemental load measure list (commercial kitchens)

- ✓ Upgrade kitchen equipment
- ✓ Use demand control hood exhaust

- **Upgrade kitchen equipment:** Table 5 highlights typical savings for various kitchen equipment, and indicates whether ENERGY STAR-qualified products are available.

Table 5. Kitchen equipment and energy savings

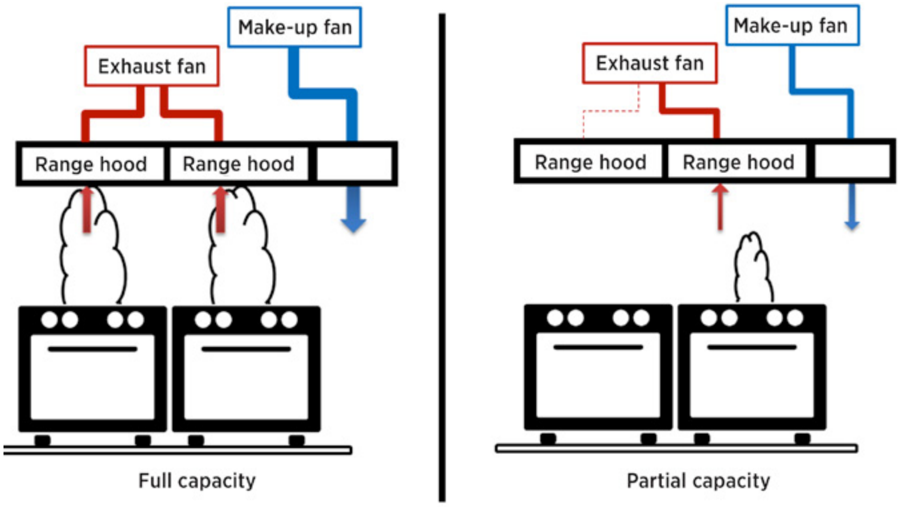
Category	Equipment	Typical energy savings	Typical water savings	ENERGY STAR-qualified
Refrigeration	Commercial refrigerators and freezers	35%	–	Yes
	Commercial ice machines	15%	10%	Yes
Sanitation	Commercial dishwashers	25%	25%	Yes
	Pre-rinse spray valves	Varies	55 to 65%	No
	Water heaters	5%	–	Yes
Food 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*

- **Use demand control hood exhaust:** Food preparation equipment and kitchen ventilation can be large energy consumers in hotel 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 to use demand control ventilation (DCV) to further reduce exhaust air flow when cooking is not taking place under the hood.

  Hood exhaust fans are controlled in response to temperature, optical, or infrared sensors that monitor cooking activity, or to direct communication with cooking appliances. 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.[26]

Figure 11. Demand control hood exhaust



Walk-in coolers and freezers

High-service hotels have food service facilities serving restaurants, bars, in-house catering and room service. These food service facilities may include walk-in coolers and/or freezers.

---

[26] energystar.gov/about/2015-emerging-technology-award-demand-control-kitchen-ventilation

Supplemental load measure list (walk-in coolers and freezers)

- ✓ Upgrade insulation
- ✓ Use fan control to turn off fans while doors are open
- ✓ Install 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 lights

- **Upgrade insulation:** Walk-in coolers should be insulated to RSI 3.5 (R-20) minimum; 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 off fans while doors are open:** Evaporator fans circulate air inside refrigerated spaces to keep temperatures consistent. Circulating air during periods when the door is open (e.g. 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.

- **Install 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 significantly reduces energy consumption.

- **Install electronically commutated motors (ECMs) on evaporator fans:** Evaporator fans typically run 24/7 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 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.

- **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 and do not take into account whether the evaporator coil actually requires defrosting. Starting the defrost cycle at regular timed intervals is important to maintain frost-free coils; however, the time to achieve the required defrosting varies according to conditions within the walk-in. To achieve the appropriate amount of defrosting, controls can be added to terminate the defrost cycle based on pressure or temperature.

- **Use free cooling:** Free cooling is a viable option for walk-in refrigerated spaces. A free cooling system delivers cold outdoor air into the refrigerated space when outdoor temperatures are suitable. The direct use of cold outdoor air can save considerable compressor and evaporator fan runtimes in many locations in Canada. For example, in Montréal, the outdoor temperature is below 4 ° 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.[27]

- **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 an open door will continue to allow warm air into the walk-in, while the cold air exits. Simple compressor controls that recognize when doors are open can eliminate this wasted energy.

- **Add door closures:** To eliminate accidental open doors and the resulting additional cooling load, door closures can be added.

- **Use air defrost for medium-temperature coolers:** Air defrost uses the evaporator fan to clear ice from the coil during periods when the compressor is off. Medium-temperature coolers are typically set to 4 °C, which is a suitable temperature for defrosting. Air defrost is the lowest energy option for medium temperatures, compared to hot gas or electric defrost, because it uses the existing conditions within the cooler.

---

[27] oesolutions.net

- **Use LED lights:** 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.[28] For comparative purposes, a 1.2-m fluorescent fixture consumes 32 W, while the equivalent LED consumes 15 W, a 52% savings.

Commercial laundry

On-site laundry facilities are common within the full range of motels and hotels.

Supplemental load measure list (commercial laundry)

- ✓ Choose high-efficiency dryers
- ✓ Choose high-efficiency commercial washers
- ✓ Use dryer vent heat recovery

- **Choose high-efficiency dryers:** Recent developments in energy-efficient laundry dryers focus on advanced moisture sensing, which allows the dryer to stop when it senses an appropriate moisture level, thereby avoiding wasting energy by over-drying. In addition, some large drying equipment achieves more efficient heat generation through the use of multi-stage or modulating gas burners, rather than the traditional method of cycling a single stage burner on and off in response to a thermostat signal.
- **Choose high-efficiency commercial washers:** High-efficiency washers combine low water use and high-speed spinning. Energy use is reduced in two ways: less hot water is used during the washing cycle, and higher spin speeds improve water extraction, resulting in a lower requirement for heat during the subsequent drying cycle.
- **Use dryer vent heat recovery:** Laundry dryers exhaust large amounts of warm, moist air to the outdoors. A typical commercial clothes dryer draws in outdoor air and heats it to dry the clothes. After circulating through the clothes, the air is exhausted, taking with it moisture and heat. In some applications, it may be economically attractive to recover the exhausted heat using an air-to-air heat exchanger to preheat the incoming air. Since the incoming air is preheated, the dryer's gas burner (or heating element) operates less, saving energy.

Figure 12. Hotel laundry

---

[28] blog.uscooler.com/retrofit-led-lights-c-store/

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

RSI is presented in m^2·K/W.

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

Conversion:

RSI = R ÷ 5.678

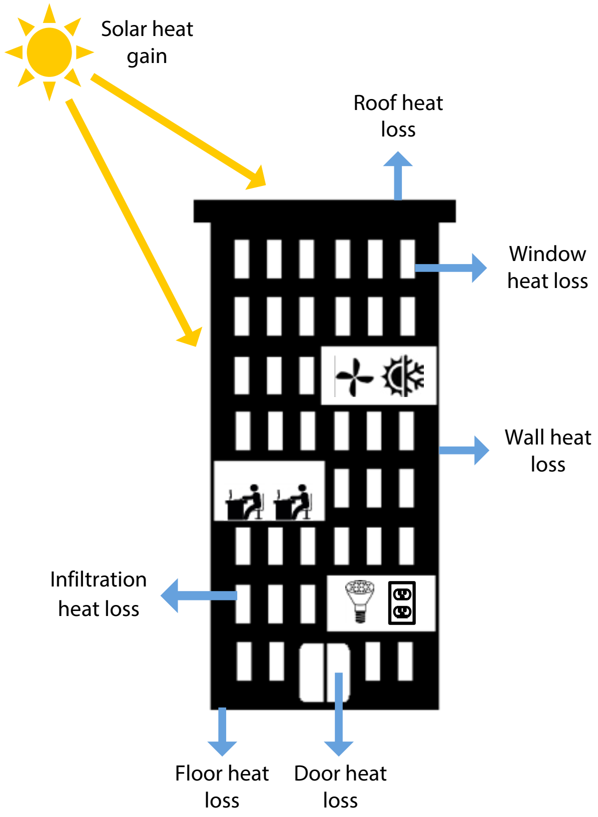
R = RSI × 5.678

1 RSI = R-5.678

Envelope

This section describes options that can be taken to improve the building envelope (roof, walls, foundation, windows and doors). The most common parameters affecting heat flow though the building envelope are conduction, solar radiation and infiltration. Conduction relates to the conductivity of the materials in the envelope assembly and their ability to conduct or resist simple heat flow from hot to cold. Performance is most often represented in RSI-values or R-values (see sidebar), or resistance to flow. Solar radiation brings wanted heat gains through the windows during the heating season and unwanted heat gains during the cooling season. Infiltration relates to air leakage through building elements, such as around windows, doors, envelope intersections, physical penetrations and mechanical openings. Figure 13 shows how heat flows into and out of a building through the envelope.

Figure 13. Building envelope heat transfer



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

The envelope considerations for an indoor pool facility (natatorium) must factor in the high humidity of the indoor environment. With humidity levels ranging between 40% and 60% in the winter, close attention must be paid to where water vapour is condensing in the envelope. Hygrothermal analysis is a critical component to proper envelope design, especially for high humidity environments like indoor pools.

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.

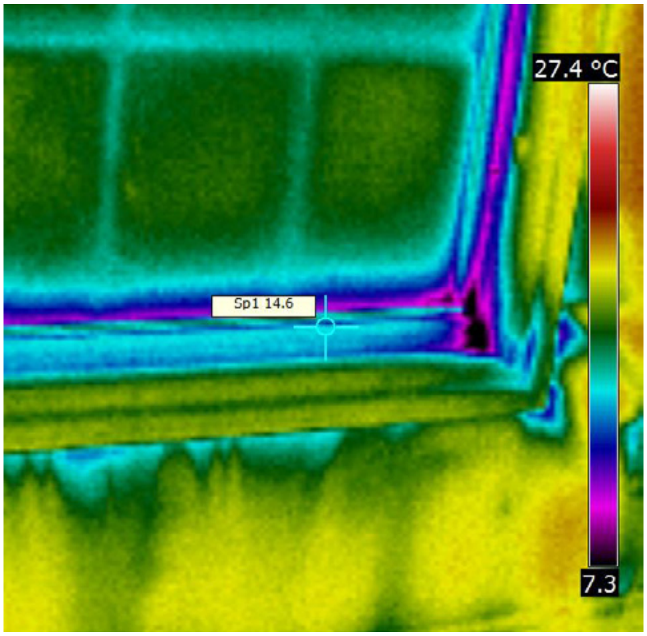
  Infiltration can also be exacerbated by a positively or negatively pressurized building. The effects of building pressurization will be experienced when a door is opened: a distinct flow of air will be felt either entering or leaving the building. Building pressure should be neutral or very slightly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

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.

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 14 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).

Figure 14. 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.

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

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

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

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

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

  Insulating and adding or improving the continuity of the air barrier has a much greater impact on the energy savings than adding insulation alone. For example, energy modelling of a 5,000-m^2 building in Toronto with a baseline infiltration rate of 7.9 L/s/m^2 (1.55 cfm/sq. ft.) retrofitted with 50 mm (2 inches) of insulation and no improvement to the air barrier saw an energy performance improvement of only 2%. By comparison, adding the same amount of insulation and reducing infiltration to 2.0 L/s/m^2 (0.4 cfm/sq. ft.) led to an energy performance improvement of 12.6%.[29]

---

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

- **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 the building occupants and is an option that should be examined when considering a life-cycle replacement of the roof. An energy analysis may show that energy savings are significant enough to warrant an early roof replacement to add the insulation.

  Wall insulation

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

- **Upgrade windows and doors:**

  Windows

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

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

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

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

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

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

Zone 5
(e.g. Kelowna, Toronto)
Wall 3.597 m^2·K/W (R-20)
Roof 5.464 m^2·K/W (R-31)

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

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

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 34 provides a more detailed discussion of each of these criteria, along with a discussion of various window components and assemblies.

Doors

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

- **Consider a cool roof option:** A "cool roof" reflects the sun's heat away from the roof, rather than transferring it to the building mass. Cool roofs increase occupant comfort by keeping the building cooler during the summer; as a result, air conditioning needs are decreased, which saves air conditioning energy costs. Furthermore, a reflective cool roof experiences less solar loading on the membrane, potentially extending the service life of the roof. However, in a heating-dominated climate, the energy savings from air conditioning may be offset by the loss of beneficial heat gains during the heating season. Results are typically site-dependent based on factors such as roof slope and snow loading. To learn more about cool roofs, visit: **www.coolroofs.org**.
- **Add a vestibule:** The NECB prescriptive path requires new buildings to be designed with vestibules and self-closing devices for all regular access doors. Since the energy saving and comfort benefits are applicable to existing buildings, vestibules should be added where feasible.

---

[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.

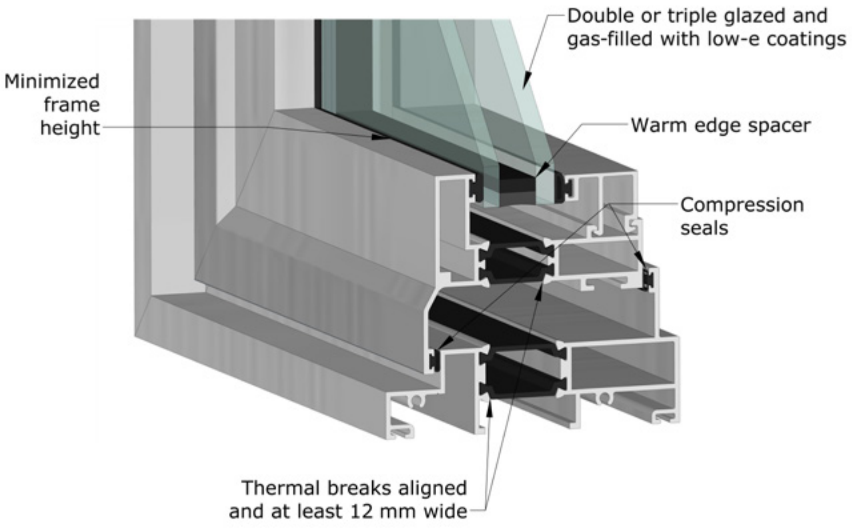
IGU performance is determined by:

- 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 15. 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

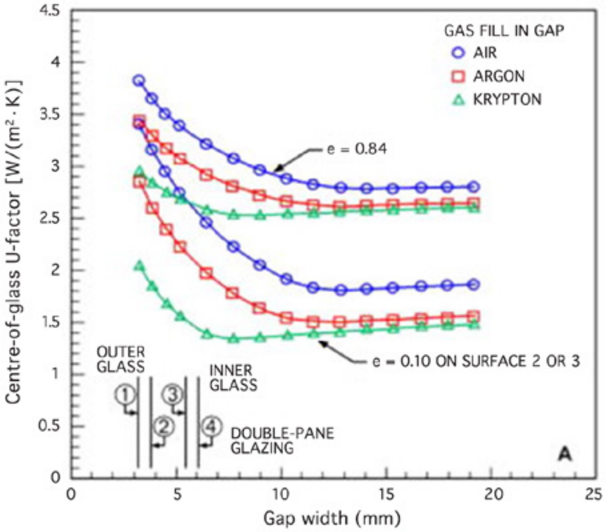
A window's U-factor incorporates the thermal properties of both the frame and the glazing. Since the sash and frame represent approximately 10 to 30% of the total area of the window unit, the frame's properties significantly influence the total window performance.

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

Figure 16. 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.

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 and health.

Packaged terminal air conditioning units (PTACs) are the main type of equipment used to condition air in guest rooms, regardless of the size of the facility. Small and medium-sized hotels and motels use rooftop units (RTUs) to condition the remaining spaces, including the corridor make-up air. Larger hotels will use a combination of systems, depending on the variety of space uses. Central boilers (and occasionally chillers) may serve air handlers when facilities contain large areas for meeting rooms, food service (restaurants and bars) and athletic facilities (gyms and spas).

Since occupant comfort is the primary concern for hotel owners, hotels require special consideration when determining options for energy savings. Allowing indoor temperatures or humidity levels outside of typical comfortable occupant conditions to save energy is generally not an acceptable option. Furthermore, common areas and food service areas operate around the clock, eliminating the option for setback temperatures and scheduled off periods. For these reasons, it is important to provide separate systems by space use. For instance, corridor make-up air that runs 24 hours a day should not share the same air handler with spaces housing daytime meeting/conference rooms.

Notwithstanding, the lowest cost option to reduce HVAC energy is to expand the allowable ranges for indoor temperature and humidity, i.e. allow temperature and humidity levels to rise during the summer months and lower during the winter. By carefully studying the thermal comfort needs of the occupants in each space type, you can determine the acceptable range for temperature and humidity. These comfort ranges can be found in ASHRAE Standard 55.[31]

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.

---

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

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 HVAC system 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 air handler with the control system providing a reset signal to the outdoor air damper to open or close according to the CO_2 in the space.

Air distribution systems measure list

- ✓ Start with first-order measures
- ✓ Use demand control ventilation
- ✓ Replace constant volume with variable air volume in multi-zone systems
- ✓ Right-size fans
- ✓ Install variable speed-drives
- ✓ Replace steam humidifiers with atomizing type
- ✓ Remove heat from entrance vestibule
- ✓ Add CO control to parking garage exhaust
- ✓ Replace existing air filters with electronic air cleaners

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

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

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

---

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

- **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 AHU 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.

  DCV is well suited to hotel areas with varying occupancies, such as lobbies, offices, meeting rooms, restaurants, gyms, etc. Economizer controls should always override demand control ventilation in control sequences.

- **Replace constant volume with variable air volume in multi-zone systems:** Typical air flow requirements for VAV systems are about 60% that of constant volume (CV) systems. The conversion of an older CV reheat, multi-zone, or dual-duct system to a modern, energy-efficient VAV system is a task to be undertaken with an experienced HVAC engineer.

  To determine the potential energy savings, you will need to model it against the existing case. Determining the return on investment is largely a function of the accuracy of the implementation costs. A schematic-level design of the system is the minimum requirement to develop a cost estimate for such an implementation.

- **Right-size fans:** Oversized fan motors result in a poor power factor, and since most utilities charge additional fees based on power factors less than 90%, right-sized fans may save both electrical energy and demand costs.

  Replacing fans with smaller, right-sized units has a low first cost and provides better occupant comfort and longer equipment life. When selecting a right-sized motor, consider upgrading to a premium-efficiency motor, installing a variable speed-drive (VSD), and using energy-efficient belts to deliver the greatest savings.

- **Install variable speed-drives:** VSDs are an efficient and economical retrofit option for any fan or pump that has a variable load. VSDs vary the motor speed depending on actual operating conditions, rather than operating continuously at full speed. When used to control fans and pumps, a 20% reduction in fan/pump speed can result in an energy reduction of almost 50%.

Figure 17. Variable speed-drives

Photo courtesy of Claudette Poirier, Vancouver Island Health Authority

VSDs are an important component in an energy-efficient VAV system. As loads decrease and VAV terminals close down, the fan speed can be reduced accordingly. Many existing VAV systems are configured with a constant speed fan and bypass damper or "dump box," where the excess air that is not delivered to the supply terminals is dumped into the return air plenum. This is a poor design, which was adopted due to the lower installed cost.

- **Replace steam humidifiers with atomizing type:** Atomizing humidifiers (also known as "adiabatic" humidifiers) reduce cooling load, reduce water waste and, in warm, dry conditions, are the most energy-efficient humidification systems. A high-pressure pump propels purified, unheated water through dispersion nozzles that produce ultra-fine water droplets. Rather than heating the water to produce steam, the high-pressure atomizing system uses heat already in the air to evaporate these water droplets.

- **Remove heat from entrance vestibule:** Many hotels 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.[33]

- **Add CO control to parking garage exhaust:** Similar to building DCV, exhaust fans for enclosed or semi-enclosed parking garages may be converted from constant to demand-based flow. Demand is typically measured using vehicle pollutant concentrations, usually CO and NO_x, as proxies. It is important to consult the National Building Code when designing these ventilation systems, since carbon monoxide is a dangerous gas and impacts life safety.

- **Replace existing air filters with electronic air cleaners:** Electronic air cleaners use two filtration technologies: a passive filter that relies on density to capture contaminants, along with electrostatic attraction to improve filtration. They have multiple benefits for HVAC systems:
  - *Lower fan power.* The static pressure drop resulting from electronic air cleaners is typically 250 Pa (1 inch) less than conventional air filters. This lowers the power consumption by the fan or allows smaller fans to be selected if the existing AHU is being replaced.

---

[33] e3tnw.org/ItemDetail.aspx?id=427

- *Improved indoor air quality.* Electronic air cleaners can filter auto emissions, bacteria and volatile organic compounds from carpets, furniture and cleaning products. By improving indoor air quality, building owners may be able to lower outdoor air levels through a monitoring program to provide further energy savings.
- *Longer service life and less maintenance.* Electronic air cleaners have lower maintenance requirements than conventional air filters, which typically require that pre-filters be changed quarterly.

Heating and cooling resizing and replacement

This section covers the main heating and cooling system types, including central boilers, RTUs, PTACs for suite heating and cooling, as well as domestic hot water systems. Measures specific to swimming pools and spas are also covered.

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.

Central heating systems

Some medium sized hotels and motels may have central heating systems served by hot water boilers.

Figure 18. Boilers

Photo courtesy of Claudette Poirier, Vancouver Island Health Authority

Many of these are more than 20 years old and operate at efficiencies of 60 to 70% due to poor design, inadequate control, piping/pumping and radiation deficiencies, excessive cycling, etc. Modern boilers can achieve efficiencies as high as 97%, converting nearly all the fuel to useful heat.

Retrofit or replacement

Boiler retrofits and replacements involve specific criteria that must be evaluated before a decision is made. These criteria impact several areas of a boiler system:

- Product life-cycle costing: Consider service life and efficiency trade-offs when choosing the boiler type (condensing versus non-condensing).
- Operations: Present and long-term needs, operating hours, downtime impact, etc.
- Physical plant: Mechanical floor area, access, power, piping systems, processes, operating personnel, etc.
- Budget considerations: Available capital expenditures, utility incentives, energy savings.

Before you decide to retrofit a boiler, you must first consider current system maintenance. If the boiler has not been well maintained, you'll probably need to replace the entire system; however, if the boiler has been maintained on a regular basis, retrofitting may be the best option. To make this determination, have a professional inspect the boiler.

While the tendency is to replace older systems with new equipment, don't underestimate the value of regular maintenance to control energy costs. Something as seemingly minor as losing flow through dirty air filters can cause a boiler system to work inefficiently. Often, employees forget to check filters, or they wait until they look dirty, which is usually several months too late.

While retrofitting is initially less expensive than purchasing a new boiler system, you must also consider whether retrofitting is the most cost effective option in the long run.

Efficiency ratings

Boiler efficiencies are commonly expressed as combustion (E_c), thermal (E_t) or annual fuel utilization efficiency (AFUE). Combustion and thermal efficiencies describe steady state efficiency; AFUE is a non-steady state measure that includes a boiler's performance when it is operating at part load and idling between calls for heat (an estimate of full operational efficiency). The minimum gas-fired boiler ratings for new buildings are described in the NECB as:

Table 6. Gas-fired boiler efficiency

NECB version	Boiler size	Standard	NECB minimum efficiency	Best available
2011/2015	<88 kW	AFUE	85%	97%
2011	88–733 kW	Combustion Efficiency (E_c)	82.5%	95%
2011/2015	88–733 kW	Thermal Efficiency (E_t)	83%	95%
2011/2015	>733 kW	Combustion Efficiency (E_c)	83.3%	85 to 95%

Heating and cooling measure list (central heating systems)

Retrofit measures

- ✓ Start with first-order measures
- ✓ Replace boiler control system
- ✓ Eliminate flow-restricting valves
- ✓ Replace standard-efficiency or oversized pumps with highly efficient units right-sized for the reduced loads
- ✓ Control heating water pumps with variable speed-drives
- ✓ Insulate heating pipes
- ✓ Replace burners

Replacement measures

- ✓ Replace with condensing boiler
- ✓ Replace with hybrid boiler system
- ✓ Replace with heat pump system

If you decide to **retrofit**, consider these options:

- **Start with first-order measures:** Existing boilers can be optimized by addressing a number of issues related to fuel combustion, water treatment and set points. It is also important to ensure that boilers are properly sequenced and that heating pipes are properly insulated. Refer to the **Existing building commissioning** stage for further details.

- **Replace boiler control system:** New developments in boiler controls create opportunities for substantial efficiency gains, including measures such as hot water temperature reset based on outdoor temperatures, optimizing the air-to-fuel ratio, improving multi-boiler staging, and adding circulation pump variable speed control.

The Holiday Inn Select Toronto Airport completed a full program of retrofits that included caulking the entire building, replacing windows, upgrading lighting, replacing five boilers with more efficient units, and replacing four condensing units from water- to air-cooled.

Source: Ontario Restaurant Hotel & Motel Association

- **Eliminate flow-restricting valves:** This measure reduces pump energy use. If valves are installed to control flow by inducing a pressure drop, energy saving measures include completely opening the valves and converting to variable speed controls, trimming the impeller or staging pumps.
- **Replace standard-efficiency or oversized pumps with highly efficient units right-sized for the reduced loads:** Most induction motors that drive pumps reach peak efficiency at about 75% loading and are less efficient when fully loaded. Wherever possible, pumps should be sized so that much of their operating time is spent at or close to their most efficient part-load factor. If a pump is oversized, it likely operates at an inefficient loading factor and negatively impacts the electrical system's power factor, potentially leading to higher demand charges.
- **Control heating water pumps with variable speed-drives:** Typically, for much of the heating season, zones only require partial heating to maintain comfort conditions. By reducing the speed of the pump to provide only the amount of heating water needed to offset the actual building heat loss, pumping energy is reduced. VSDs can ensure that pumps perform at maximum efficiency at part-load conditions. The power required to operate a pump motor is proportional to the cube of its speed. For example, in a pump system with a VSD, a load reduction that results in a 10% reduction in motor speed reduces energy consumption by 27%.[34] With proper controls, lower heating water flow rates enabled by VSD pumps can also be coordinated with a hot water temperature reset schedule to meet loads accurately and efficiently. Low heating loads, for example, might be most efficiently met by creating warmer heating water and reducing the flow rate to save pump energy.
- **Insulate heating pipes:** Minimum pipe insulation levels for HVAC water heating systems for new buildings are governed by Table 5.2.5.3 in NECB 2011 and 2015, which can serve as a guide for retrofits. Thickness of insulation values are determined based on the diameter of the pipe and water temperature, using a prescribed range of insulation conductivity. For example, Table 7 indicates the insulation thickness for a typical hydronic heating system.

Table 7. Insulation thickness by pipe diameter for a typical hydronic heating system

NECB	Temp	U-value	25 mm	32–51 mm	64–102 mm	>127 mm
2011	61–93 °C	0.036–0.042	25.4 mm	25.4 mm	38.1 mm	38.1 mm
2015	61–93 °C	0.036–0.042	38.1 mm	50.8 mm	50.8 mm	50.8 mm

---

[34] The formula is $1 - (0.9)^3 = 0.27$.

- **Replace burners:** New burners for all types of boilers and fuels are commercially available, and many suppliers offer burner retrofit parts for modifying burners rather than fully replacing them. This can often achieve significant improvements at lower cost than a full replacement.

  The potential for efficiency gains from new burners is a function of the difference between the old and new technologies. Levels of fuel and unburned fuel (from incomplete combustion) and the amount of excess air between the new and old burners will dictate the performance improvement potential. Furthermore, the burner size and turndown capability (i.e. the ability to operate efficiently at less than full load) will impact the losses associated with inefficient low loads and on/off cycling duty.

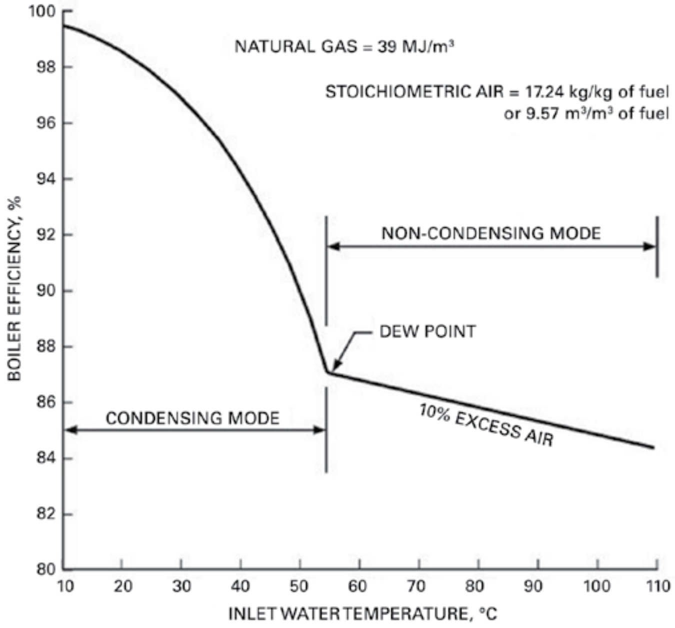
  With respect to size/turndown capability, most gas burners exhibit a turndown ratio (the ratio of capacity at full fire to its lowest firing point before shutdown) of 10:1 or 12:1 with little or no loss in combustion efficiency. However, some burners offer turndown ratios of 20:1. A higher turndown ratio reduces burner startups, provides better load control, saves wear and tear on the burner, and reduces purge air requirements, all resulting in better overall efficiency.

If **replacement** is your best option, three measures can be considered: high-efficiency condensing boilers, hybrid systems and heat pumps.

- **Replace with condensing boiler:** Condensing technology recovers the latent energy contained in the condensing flue gases—part of the energy that normally disappears up the chimney in other heating systems. With condensing technology, the water vapour contained in the flue gases condenses on the cooler heat exchanger surfaces of the boiler, transferring heat into the boiler water. The heat released from condensation is transmitted directly into the boiler water, minimizing thermal flue gas losses. The seasonal efficiency of condensing boilers can reach up to 97%.

  The first cost of condensing boilers is higher than that of traditional non-condensing boilers. The challenge a designer faces is to ensure that return water temperature to the boiler stays below 54.4 °C (130 °F); otherwise, boiler efficiency drops significantly, as shown in Figure 19, and the condensing boiler operates in non-condensing mode. Under these conditions, the premium paid for the higher condensing efficiencies is lost, thus reducing the return on investment.

Figure 19. Return water temperature and its impact on boiler efficiency



Source: 2012 *ASHRAE Handbook – HVAC Systems and Equipment*. © ASHRAE. ashrae.org

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

- **Replace with hybrid boiler system:** A hybrid boiler system consists of condensing and non-condensing boilers controlled to deliver the maximum efficiency over the heating season. Depending on the system design and heat loss from the building, distribution water temperatures may not be suitable for a condensing boiler. This is often the case during peak heating conditions. Therefore, when outdoor temperatures are coldest, it is more economical to operate a modulating non-condensing boiler since the elevated return water temperatures will not permit condensing operation. However, during the majority of the season, when heating demands are much less than peak, supply temperatures can be decreased, with return water temperatures below the 54.4 °C (130 °F) threshold for condensing operation.

  To overcome these seasonal demand differences, a boiler system that uses a smaller condensing boiler during the shoulder seasons and a larger non-condensing boiler during the winter season will provide a better return on investment. The hybrid system will stage the boilers to engage the condensing boiler until return water temperatures no longer permit condensing operations. At this point, the system will engage the modulating non-condensing boiler and turn off the condensing boiler.

A **modulating boiler** adjusts its output by sensing the outdoor air and/or return air temperature and then adjusting the firing rate as low as possible to meet the heating needs.

- **Replace with heat pump system:** Heat pumps transfer heat by circulating a refrigerant through heat exchange coils, completing a cycle of evaporation and condensation. In one coil (evaporator), the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed on the way to the other coil (condenser), where it condenses at high pressure. At this point, it releases the heat it absorbed in the evaporator. The heat pump cycle is reversible, whereby heat can be absorbed from the indoor environment and rejected outdoors or absorbed from outdoor air and rejected into the indoor environment. Heat pumps may be air source or coupled to the ground or a body of water. Ground coupled units are often referred to as ground-source heat pumps (GSHP); the industry at large has adopted the term "geo-exchange" for non-air-source heat pumps. A geo-exchange heat pump can be either open loop, which circulates ground or surface water to the heat pump, or closed loop, which circulates fluid in a closed loop and exchanges heat through the pipe walls. Systems can be centralized or distributed for multi-zone control and distribution.

  Distributed heat pumps used in variable refrigerant flow (VRF) systems have efficiency advantages over centralized systems and can be fed by an air-source heat pump, a ground heat exchanger or a central boiler. The benefit of these systems is that heat can be exchanged directly within the building loop, reducing the thermal load on the ground heat exchanger or central boiler. See **Guest suite equipment** for further details.

  In a heating-dominated climate with high electricity costs and low natural gas costs, heat pump retrofits are often less financially attractive than other options. Most favourable conditions are present when existing equipment is at the end of its expected service life and replacement is necessary regardless of the resulting efficiency gains. Detailed estimates of costs and savings over the expected lifetime of the heat pump system should be determined to properly assess the financial feasibility of any given project.

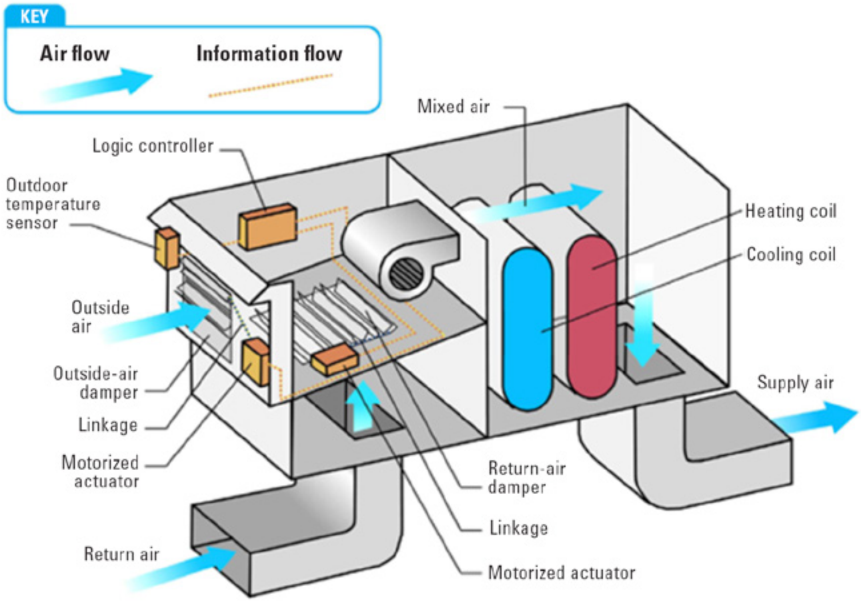
Rooftop units

More than a third of Canadian commercial/institutional building floor space is conditioned by self-contained, packaged rooftop units.[35] RTUs are typically configured with natural gas combustion or electric duct heaters for heating and direct expansion (DX) refrigeration cooling. In some cases, heat recovery wheels or cores are included as well. The RTU may also be configured as a heat pump or, in rare cases, the RTU heating may be delivered through a hot water coil served by a central boiler plant. In addition, units may be constant volume or variable volume. A typical RTU setup is shown in Figure 20.

---

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

Figure 20. 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 8 illustrates how ASHRAE's RTU efficiency standards have evolved.

Table 8. Evolution of RTU efficiency standards

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

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

- Energy efficiency ratio (EER), defined as the rate of cooling in Btu/hour divided by the power input in watts at full-load conditions, is a measure of full-load efficiency. The power input includes all inputs to compressors, fan motors and controls.
- Integrated energy efficiency ratio (IEER), defined as the cooling part-load efficiency on the basis of weighted operation at various load capacities, applies to RTUs with cooling capacities equal to or greater than 19 kW (5.4 tons).
- Seasonal energy efficiency ratio (SEER) describes the seasonally adjusted rating based on representative residential loads, unlike EER, which describes the efficiency at a single rating point. SEER applies only to RTUs with a cooling capacity of less than 19 kW. Although units less than 19 kW that use three-phase power are classified as commercial, they still use the residential SEER metric. This is because these small units are similar to the single-phase units used in residential applications, which have a large part of the market share in this size range. Older units of less than 19 kW often have a SEER rating as low as 6, compared to modern RTUs with a range of 12 to 16.8 SEER.

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

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

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

Heating and 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 measure

- ✓ 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 CV system into a variable flow system with demand control and economizer is available. A field study by the Pacific Northwest National Laboratory[36] 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.

---

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

- **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 will deliver energy savings. If the existing RTU cannot accept the economizer as a retrofit, a new RTU should be considered.
- **Modify controls to enable early morning flush during the cooling season:** During the cooling season, pre-cool the building with 100% outside air (when outdoor air conditions permit) before starting mechanical cooling. To accomplish this, the controller senses acceptable outdoor air conditions and delivers an override signal to the outdoor air or economizer damper to open fully. During this operational mode, heat recovery must be disabled to take advantage of the free cooling.
- **Modify controls to close outside air dampers during morning warm-up during the heating season:** Programming the space temperature set point lower during unoccupied hours is a common practice for energy savings. The temperature is then returned to the occupied period set point before occupants arrive. While warming the space before the occupants arrive, make sure the outside air dampers are fully closed. This saves energy by heating recirculated air, rather than colder, outside air.

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

- **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:

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

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

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%.

- Insulated cabinets for improved energy efficiency and acoustics
- Multi-staged or modulating heating control with turndown ratio of 10:1
- Variable speed electronically commutated fan motors
- Variable speed scroll compressors with superior part-load efficiency
- Heat and energy recovery from exhaust air
- Demand controlled ventilation using CO_2 sensors
- Heat pump option
- SEER up to 16.8; IEER up to 21
- Remote energy monitoring and operational supervision

Condensing type heating RTUs with 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.

Guest suite equipment

On average, hotels surveyed in the U.S. spend about $2,196 per guest room each year on energy.[37] The percentage of a facility's total energy use depends on the level of service the hotel offers. In typical limited service hotels or motels, packaged terminal air conditioners (PTACs) may represent 50% or more of total energy use. The impact of PTACs in full service hotels, with restaurants, meeting facilities and spas, is less significant, but they still present an opportunity to save energy.

The opportunity for energy savings is largely dependent on the percentage of time a room is actually occupied. A hotel may have rented 100% of their rooms, but the average time guests spend in their rooms is approximately 50%.[38] During unoccupied periods, guest room temperatures can be allowed to drift outside of the normal occupied temperature range, thus reducing the heating or cooling load. Occupancy sensing and control can achieve energy savings in the range of 25 to 44% per suite according to industry studies.[39]

---

[37] energystar.gov/sites/default/files/buildings/tools/SPP%20Sales%20Flyer%20for%20Hospitality%20and%20Hotels.pdf

[38] San Diego Gas & Electric, Emerging Technologies Program, Hotel Guest Room Energy Controls Final Report saw an average of 44–53% actual occupancies in their study group. cltc.ucdavis.edu/sites/default/files/files/publication/2008_sdge_hotel_energy_controls.pdf.

[39] seedengr.com/documents/IncreasingEnergySavingswithHotel-RoomAutomation.pdf

The most common equipment for heating and cooling guest suites is the PTAC and, although the name suggests that it only provides cooling, these units are equipped with electric resistance heating or are configured as heat pumps. The majority of units in Canada have been installed with electric resistance heating. PTACs are prevalent due to their simplicity of installation, lower capital cost, simple operation and minimal maintenance. To save energy, older PTACs can be replaced with new, more efficient units, or existing units can be retrofitted with control points and connected to an energy management system.

PTACs should also include humidity control. Typically, if space temperatures are within the set point range, but the humidity levels increase beyond 60% relative humidity, an override control will bring in fresh, dehumidified air through the PTAC.

Heating and cooling measure list (guest suite equipment)

- ✓ Start with first-order measures
- ✓ Install occupancy controls
- ✓ Use an energy management system for packaged terminal air conditioners
- ✓ Replace packaged terminal air conditioners with high-efficiency models
- ✓ Replace packaged terminal air conditioners with central plant-supported systems

- **Start with first-order measures:** Existing PTACs can be optimized by regularly cleaning the coils and ensuring that there are no gaps between the units and the building envelope. Refer to **Existing building commissioning** for further details.

- **Install occupancy controls:** Wireless occupancy sensors and control units can be added to existing PTACs to incorporate temperature setbacks during unoccupied periods. A typical retrofit kit includes a battery-powered sensor that incorporates infrared occupancy and ambient temperature sensing. The control unit plugs into the 120-/240-V receptacle at the PTAC, and the PTAC plugs into the controller. The controller has an antenna that receives signals from the sensor.

  During unoccupied periods, the suite temperatures are allowed to drift outside of the occupancy set point. When space temperatures exceed the unoccupied set point, the sensor sends a signal to engage the PTAC to run until the unoccupied set point is reached.

  During occupied periods, the on-board controller with manual adjustments can be controlled directly at the PTAC by the occupant, disabling the wireless temperature sensor. The occupant has full control of heating and cooling temperatures within the limits of the PTAC on-board control. See the **Business Case Guidance** section for information on the costs and benefits of an example upgrade scenario.

- **Use an energy management system for packaged terminal air conditioners:** The next level of control for guest rooms is to integrate the room thermostat control with a central building automation system. Such a system incorporates occupancy sensing and integration with the room booking system. This enables space temperature set point adjustments for periods when the room is not booked, within an hour of the expected arrival time and occupied mode. A sample set point schedule presented in Table 9 demonstrates how temperature setbacks can be applied to balance energy savings and occupant comfort on arrival.

Table 9. Sample guest room set point schedule

Occupancy mode	Heating set point	Cooling set point
Occupied mode[40]	20 °C	24 °C
Unoccupied mode (room booked, or within one hour of arrival)	19 °C	25 °C
Unoccupied mode (room not booked)	18 °C	26 °C

- **Replace packaged terminal air conditioners with high-efficiency models:** In recent years, efficiencies for PTAC products have improved. Units older than 10 years may have cooling EERs of 5.0 or 6.0. With age, units can deteriorate to where actual operating efficiency drops to an EER of 3.0 or 4.0. Efficiency gains have been made in the following areas:
  - Standard rotary compressors replaced with scroll or rotary compressors with variable speed capability
  - Heat exchangers with larger areas or more effective transfer characteristics (microchannel or microgroove technologies) to deliver more of the available cooling and heating
  - Improved fan performance and sound levels for more effective ventilation, less energy consumption and better acoustic comfort
  - Improved insulation and sealant to reduce unnecessary heat transfer to the surrounding wall
  - Built-in occupancy control and optional energy management interface

---

[40] Default setting, adjustable by occupant.

- **Replace packaged terminal air conditioners with central plant-supported systems:** Replacing PTACs with systems supported by the central plant requires significant re-engineering, adequate space on the roof and/or in the mechanical room for equipment, and interior renovations to accommodate distribution piping. Redundant central plant equipment must also be installed to provide back-up and avoid total building shutdown in the event of mechanical service or repair. Depending on the system selected, the central plant may provide heat recovery when the building has simultaneous heating and cooling, provide a higher coefficient of performance (COP) throughout the heating season, have terminal units that do not penetrate the building envelope in every room (reducing air infiltration), and be efficiently connected to future energy sources such as geo-exchange heat pump systems. There are two central plant-supported systems that warrant consideration: four-pipe fan coils and VRF heat pumps.

  Four-pipe fan coils

  Four-pipe fan coil systems typically include a central chiller, a boiler and a four-pipe distribution system consisting of chilled and heating water supply and return pipes. A fan-coil unit, located in each room, includes a heating and cooling coil so that each space can have independent control whenever heating or cooling is required. During simultaneous heating and cooling within the building, any heat recovery would take place in the mechanical room where the chiller and boiler are located. Since there are no compressors within the fan-coil units, noise levels and maintenance are lower with this type of system.

  Variable refrigerant flow (VRF) heat pumps

  VRF systems are composed of distributed heat pumps that serve each guest room's conditioning needs. Systems can be configured to deliver simultaneous heating in some rooms and cooling in others, a functionality required by many hotel facilities during shoulder seasons. For example, the south side of a building may experience heat gains, and thus require cooling, while the north side requires heating. With a three-pipe VRF, cooling heat rejection is transferred to the zones requiring heating. VRF systems are 25% more efficient than traditional HVAC systems; however, because these systems often rely exclusively on electricity, which is generally more expensive than natural gas, a cost-benefit analysis should be conducted to determine if VRF is a viable option for your facility.

Packaged terminal heat pumps (PTHP)

Another option to consider is PTHPs, also known as heat pump PTACs, which use a reverse-cycle refrigeration system for heating and include a supplemental heat source. Currently, the most common type of supplemental PTAC heating comes in the form of electric resistance heating. However, PTHP units, specified with supplemental heating, can achieve annual heating energy savings of approximately 30%,[41] when compared against standard PTACs. See the **Business Case Guidance** section for information on the costs and benefits of an example upgrade scenario.

---

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

Domestic hot water

Domestic water heating represents close to 20% of the energy used in Canadian hotels and motels, a significant load compared to other sectors. Luckily there are a number of opportunities to save energy.

Heating and cooling measure list (domestic hot water)

- ✓ Install low-flow aerators and showerheads
- ✓ Insulate domestic hot water pipes
- ✓ Preheat domestic water with solar thermal technology
- ✓ Replace existing boiler/heater with more efficient unit

- **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. See the Business Case Guidance section for information on the costs and benefits of an example upgrade scenario.
- **Insulate domestic hot water pipes:** Minimum pipe insulation levels for service water heating systems in new buildings are listed in the NECB, and can be used as guidelines for retrofits. The thickness of insulation is determined based on the diameter of the pipe and ambient conditions of the location, using a prescribed range of insulation conductivity. For example, Table 10 indicates the insulation thickness of a 25 mm (1") pipe.

Table 10: Minimum insulation thickness for DWH pipes (NECB 2011 and 2015)

Location	Insulation U-value	Minimum thickness
Conditioned space	0.035–0.040	25.4 mm
Unconditioned or outside	0.046–0.049	63.5mm

- **Preheat domestic water with solar thermal technology:** For hotels and motels in regions with adequate sunshine availability, solar hot water systems can be designed to deliver 50 to 60% of the domestic hot water demand. In some regions, systems can deliver close to 80%.

  Solar collectors for domestic water heating come in two forms: flat plate and evacuated tube.

Sunny ideas!

Twenty **solar collectors** on the Listel Hotel in Vancouver are connected to a ground-source heat pump and a heat recovery system, as well as a 20-ton air-to-water heat pump. The solar-heated water is stored in a 4,500-litre tank and is used primarily to preheat domestic hot water. The system reduces natural gas use by about 30%. The estimated payback was less than six years, based on an estimated 5% annual increase in natural gas rates and taking into account a grant from the ecoENERGY for Renewable Heat Initiative.

Source: The Listel Hotel, thelistelhotel.com/about.html

- Flat plate collectors (see Figure 21) consist of a painted metal absorber panel attached to copper pipes where water or a heat transfer liquid passes through. The absorber and pipes are encased in a metal frame, surrounded by thick insulation to help retain the collected heat, and protected by a sheet of glass or glazing, which creates an insulating air space.

Figure 21. Flat plate collectors

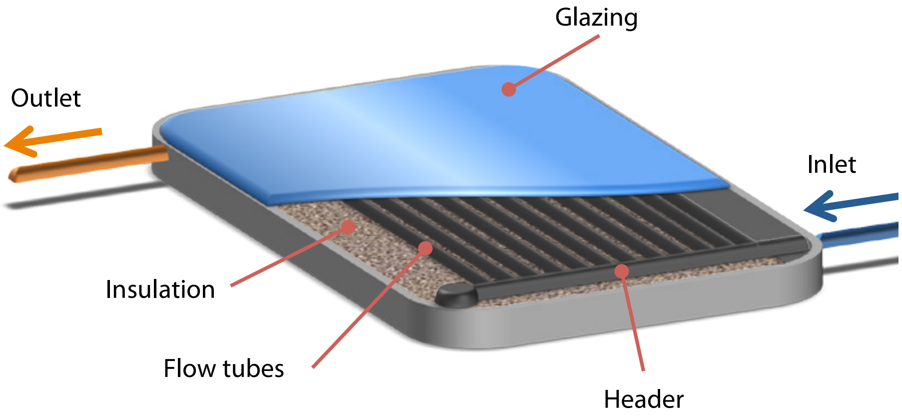


Photo courtesy of Claudette Poirier, Vancouver Island Health Authority

- Evacuated tube collectors (see Figure 22) consist of heat pipes surrounded by glass tubes under a vacuum. Each tube works like a thermos, with the evacuated air space around the heat pipe providing an almost perfect insulator and delivering highly efficient solar collection under cold outdoor air temperatures.

Figure 22. Evacuated tube collectors

Photo courtesy of Claudette Poirier, Vancouver Island Health Authority

In 2011, Travelodge Hotel Saskatoon installed 57 evacuated **solar tubes** on its roof. The thermal energy is used to warm the hotel's swimming pool and the domestic hot water for about 25% of the hotel's guest rooms.

Source: Green Lodging News, **greenlodgingnews.com/travelodge-hotel-saskatoon-installs-57-solar-collectors**

Collector for collector, evacuated tubes can cost around 20 to 40% more to buy than flat plate collectors. However, price alone should not be used to determine which collector to select. Through simulation, the year-round performance of the two collector options can be compared. In cool climates, evacuated tube collectors will generally have a lower cost per GJ of heat supplied.

- **Replace existing boiler/heater with more efficient unit:** Existing hot water boilers/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.

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.

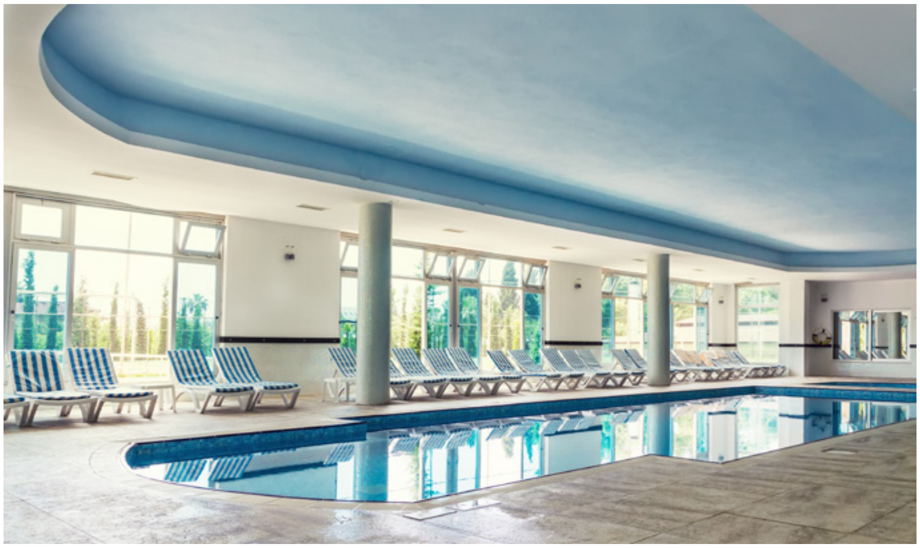
Swimming pools and spas

Indoor swimming pools and spas, also referred to as natatoriums, are significant consumers of energy. Studies conducted by the Smart Energy Design Assistance Center[42] show that energy consumption in natatoriums is dominated by the following end uses: ventilation, dehumidification, pool heating and pool pumping.

---

[42] smartenergy.illinois.edu/fact-sheets-building-type/pools

Figure 23. Hotel pool



All indoor pool facilities are equipped with dehumidification systems that use refrigeration to condense the moisture from the recirculated air stream. Dehumidification systems are critical to protect building elements and prevent mold growth. Packaged systems are available that recover the condensate for pool make-up water and reheat the air stream or pool water.

Heating and cooling measure list (swimming pools and spas)
✓ Use pool covers during unoccupied hours
✓ Minimize ventilation flow rates
✓ Optimize humidity levels
✓ Maintain pool temperature at a maximum of 26 °C
✓ Dehumidify with heat recovery
✓ Replace filter pumps with high-efficiency models
✓ Replace filter pumps with variable or two-speed pumps
✓ Use solar hot water and pool heating

- **Use pool covers during unoccupied hours:** Swimming pools lose energy in three ways: evaporation (70%), ventilation (27%) and miscellaneous system losses (3%). The single most effective way to save energy is to mitigate the amount of evaporation through the use of pool covers during unoccupied periods.

Energy loss through evaporation[43]

Consider an indoor aquatics facility that has a 25 x 20-metre pool with 26 °C (80 °F) water and 28 °C (82 °F) interior air at 50% relative humidity. Under these conditions, approximately 98 litres of water and 66 kWh of energy are lost every hour. Deploying a pool cover during unoccupied hours virtually eliminates the evaporation losses, reducing the load on the dehumidification and pool water heating systems.

---

[43] Illinois Smart Energy Design Assistance Center. May 2011. *Energy Smart Tips for Swimming Pools.*

- **Minimize ventilation flow rates:** ASHRAE Standard 62.1 recommends a minimum outdoor rate of 2.29 L/s/m^2 (0.45 cfm/sq. ft.) of pool area and deck.[44] The standard also requires additional ventilation for dehumidification, recommending four to six air changes per hour. Indoor pool environments require constant dehumidification, and circulation fans must operate accordingly to maintain acceptable humidity levels. However, outdoor air rate ventilation is only required during occupied periods. During unoccupied periods, the outdoor air damper can be closed off to save energy. Additionally, it is also recommended to maintain a slight negative pressure in the natatorium to keep warm moist air from migrating into building assembly and pool odours from seeping into adjacent spaces.

- **Optimize humidity levels:** ASHRAE recommends that indoor relative humidity (RH) levels be maintained between 40 and 60%. RH levels below 50% increase the rate of evaporation from the pool and the occupants. Above 60%, there is a risk of mold growth and other building material degradation issues. The more dehumidification required, the greater the energy consumption. RH levels can be varied according to outdoor conditions to minimize the energy consumed and protect the building envelope. Maintaining an RH of 50% provides a good balance of occupant comfort, envelope protection and energy conservation. However, during the summer months when ambient humidity is higher, the RH in the natatorium can be allowed to rise to 60% to reduce the dehumidification energy requirements.

- **Maintain pool temperature at a maximum of 26 °C:** ASHRAE recommends pool water temperatures of 26 to 29 °C for hotels. Pool water heating energy can be minimized by maintaining pool temperatures at 26 °C.

- **Dehumidify with heat recovery:** There are number of packaged dehumidification systems available that reject the heat back into the air stream or pool make-up water. Systems may be configured as heat pumps, regular condensing or desiccant dehumidification with energy recovery. If the existing dehumidification system rejects heat to the outside, there is a solid case for converting or replacing the system with the more advanced options that dominate the market today.

- **Replace filter pumps with high-efficiency models:** Pool filter pumps serve a vital role in maintaining a healthy swimming environment. Pool water in a hotel environment must be pumped through filters 24 hours a day to ensure suitable water quality. To save energy, properly-sized, high-efficiency pumps and motors should be used.

---

[44] Rates based on pool facilities without spectator seating.

- **Replace filter pumps with variable or two-speed pumps:** The main purpose of a pool pump is to circulate water from the swimming pool through a filter. In many cases, pumps have been selected that are single speed and oversized. Many swimming pool pumps perform multiple functions, and traditionally the pump is sized for the most demanding task, such as circulating pool water through a heater, energizing spot jets, or vacuuming the pool. However, most of the time, the pump is merely circulating water though the filter. To save energy, multi-speed pumps can be applied to better match the speed of the pump with the task being performed. In addition, slower pumping speeds allow for better and more effective filtration.

  Two-speed pumps are configured with full-speed and half-speed operation, saving approximately half the energy consumed by a single-speed pump. Variable speed pumps are a superior option, yielding savings up to 80%, compared to the single-speed pump; they are also quieter and require less maintenance.[45]

- **Use solar hot water and pool heating:** As outlined in the Domestic hot water section, solar thermal systems are a viable opportunity to save energy where sufficient sunlight is available. In cases where the heat recovery from dehumidification is insufficient to heat the air and pool water, solar may be the most economical method of heating the pool water for parts of the year.

  Stand-alone solar thermal systems for pools are designed very differently than for domestic water. Pool systems are typically designed for seasonal use, circulating the pool water through the collectors. For year-round use, solar thermal systems are designed with a glycol-based collector loop connected to the pool water via a heat exchanger.

---

[45] cee1.org/content/cee-dives-swimming-pools

PART 1

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

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

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

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

Toll-free: 1-877-360-5500

THE FOUR SEASONS HOTEL, VANCOUVER: A CASE STUDY

PART 2

The Four Seasons Hotel in Vancouver has one of the smallest carbon footprints of any hotel in Canada and is one of only 37 hotels worldwide—and the only Forbes 5 Star property—to be awarded the highest rating (5 Keys) by Green Key Global.[46]

> “You’ve got to be committed to energy savings. It has to become part and parcel of your daily routine and life. If you’re not committed, nothing will be easy.”
>
> – Priyan Jayetileke, Director of Engineering

Suite at the Four Seasons Hotel, Vancouver, BC

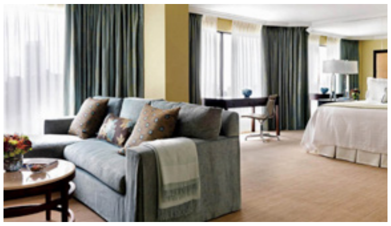


Photo courtesy of the Four Seasons Hotel

The Four Seasons Hotel began its push toward greater energy efficiency in 2008 when it was bidding to host the Green Meeting Industry Council’s annual conference. Council members spoke with staff, then toured the hotel.

“When the tour was over, one of the members had just finished a soft drink and told me that she wanted to follow the can,” recalled Priyan Jayetileke, Director of Engineering. “We didn’t have a formal recycling program back then, and she followed the staff member who picked up the garbage, all the way to the dumpster.” As embarrassing as that was, the Council recognized the green initiatives the Four Seasons had already taken and staff’s willingness to do more in future. The hotel won the conference bid and since then, the Four Seasons has emerged as a leader in sustainability within the hospitality industry.

Major benefits

- ✓ The Four Seasons has saved more than $1.1 million in energy costs since 2012.
- ✓ Since 2012, electricity consumption has been reduced by more than 10,000 MWh.
- ✓ In 2014, the hotel reduced steam consumption by 2.5 million pounds.
- ✓ GHG reductions in 2014 were about 195 tonnes, the equivalent of removing 4,100 cars from the road permanently.

---

[46] Green Key Global is an environmental certification body whose programs and standards are designed for the hotel/motel industry. greenkeyglobal.com/

Getting informed

The Four Seasons has been a member of BC Hydro's Power Smart program for many years and a member of its Continuous Optimization Program since 2012. It is also a member of the Green Key Eco-Rating Program designed by the Hotel Association of Canada, which provides verification audits and other support to the industry. These programs have provided a variety of resources that have helped improve the hotel's energy performance.

Under Power Smart, for example, BC Hydro provided funding for an on-site engineer. "He created a baseline from three years' worth of energy data," said Jayetileke. "He did readings for both winter and summer and took an average."

Jayetileke is also part of a group of chief hotel engineers, who meet through the Vancouver Facilities Management Association. Members regularly review the energy data from all of the city's hotels and benchmark their performance against others in the industry.

The retrofits

The payback period is often the key factor when planning new projects, Jayetileke said, but added that the hotel does follow a similar process to the one that NRCan recommends (assess, plan, implement, maintain). The 2012 BC Hydro audit report contained 42 recommendations; the hotel implemented 23 of them.

The Four Seasons was already seeing tremendous savings from a propane-electric boiler system that had been installed at its resort hotel in Whistler.[47] On a $250,000 investment, the payback period was one year, and the upgrade has, to date, saved the hotel more than $2 million in energy costs. Jayetileke oversaw the Whistler project and thought that a similar system would work for the Vancouver hotel as well.

"At the time, natural gas prices were going through the roof, and hydro was cheap," Jayetileke explained. In 2009, the hotel installed an electric-gas boiler system. The challenge was finding the best location for it. "We finally installed it on the fourth floor, close to an electrical transformer. We can switch between the two energy sources so now, when hydro has gone up and gas is cheaper, we're still saving on energy costs."

The majority of the hotel's lighting—guest rooms, lobbies, staff areas, corridors, Exit signs, etc.—has been switched to LEDs. Motion sensors were also installed in the housekeeping corridors and in the linen closets of guest rooms.

Additional measures have included low-flow fixtures in guest rooms, and variable speed-drives on all kitchen fan equipment, a move that reduced fan hood-related consumption by more than a third.

---

[47] Whistler did not yet have a natural gas pipeline when the boiler was installed.

Monitoring

The Four Seasons uses two programs to monitor energy use. The first, i-Vu, identifies points where energy can be saved; the second, PULSE Energy, monitors daily energy use. As part of its membership in BC Hydro's energy programs, the hotel has access to energy tracking software that provides key data for monitoring the performance of its systems. The data also provides senior management with the information they need to plan future energy efficiency investments.

"Shift engineers log in and out of PULSE Energy every day, and we have a competition to see who can run the hotel the best in a shift without compromising the function," said Jayetileke.

Jayetileke empowers his engineers to make their own decisions about energy management, so long as it doesn't compromise staff or guest comfort. "For example, I started playing with set points for cooling. It didn't need to come on at 5:30 a.m., which is what it was originally set at. We can start it later, and the hotel will still be cool enough for guest comfort. We can always tweak things."

How are retrofits financed?

Payback is the Four Seasons' most important criterion when deciding retrofit measures to take. Three years is the average payback period for most of the measures implemented at the hotel.

"We have an annual capital fund, but anything more that I want to do has to go to the planning committee, then the general manager, the vice-president and the head office," said Jayetileke, who noted that his capital budget is about $2 million a year. "I will pick projects and try and squeeze them in under that budget, but it's tougher to get money these days. The only way I can sell energy efficiency improvements is to show [senior management] the bottom line. If I can convince them that an investment will save so many dollars per year, I'll get that money."

Community and employee engagement

A green committee composed of a staff member from each department meets regularly to discuss energy issues and brainstorm new ideas, such as composting food waste.

"We have posters to remind staff to do certain things, like turn off lights. We also have a great security team that checks all the lights and reports to me," said Jayetileke. "What we stress is that whatever staff members do at home, they should do it at the hotel."

In 2015, the City of Vancouver banned organic waste from landfill. "That was a huge kick in the butt for everyone," said Jayetileke. "One of our staff members helped organize the cafeteria so that all organic waste is now separated."

All guests receive a pamphlet that lists the hotel's sustainability efforts and programs, and guests can also contribute through the Eco-luxury program. Rocks are collected from the beach and left in each guest room. By leaving a stone on the bed, guests can indicate to housekeeping that they don't want their towels or linens changed. Last year, 11% of guests participated, saving the hotel about $20,000.

The Four Seasons also partners with community organizations such as Ronald McDonald House, the United Way, Lion's Club and the Terry Fox Foundation. "We try to be part of the community because sustainability isn't just about energy savings."

Advice

When asked what he would do differently if he could do it again, Jayetileke said that he would have developed multi-year asset management plans.

"I would have looked at all major equipment and its operating criteria," he said. "But we didn't have time to do that because we were running the building." He said that's where utility programs really came in handy: "We were looking for an advisor relationship, and it was so important for BC Hydro to help our business."

For other hotel owners and managers, his advice is simple: commitment. "You have to be committed. Even if you're not a manager, you have to be the driving force to get things done."

Having the support and engagement of staff is also a key element. "When you can show them the numbers and compare what they do at work to what they do at home, they get the point. If you're not committed, you can't ask that of other people."

Priyan Jayetileke, Four Seasons Director of Engineering

Photo courtesy of the Four Seasons Hotel

> "When groups select our hotel to stay at, they want to know how sustainable we are. Sustainability has become a real selling point."
>
> – Priyan Jayetileke

BUSINESS CASE GUIDANCE

PART 3

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

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

Business case analysis methodology

Cost-benefit information has been calculated or modelled for each example retrofit measure using a number of general input assumptions. To develop **annual savings estimates**, upgrade measures were analyzed under conditions typical of a 30-year-old, 5,000-m^2 hotel. 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 Montréal 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**[48] estimates, marginal utility rate data was sourced from the three cities above.[49] 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.

---

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

[49] Vancouver: $35.60 per incremental GJ of electricity, and $7.367 per incremental GJ of natural gas.
Edmonton: $29.10 per incremental GJ of electricity, and $5.296 per incremental GJ of natural gas.
Montreal: $22.10 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 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
Montréal	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 per fixture

Replace 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
Montréal	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 per fixture

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
Montréal	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 per fixture

Replace parking garage 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	2.9	$120	$81	$899	69.2%	1.5
Edmonton	2.9	$120	$66	$712	56.8%	1.8
Montréal	2.9	$120	$50	$511	43.4%	2.4

Measure-specific assumptions and notes:

- Based on replacement of 150-W MH (metal halide) with 107-W LED
- 24 hours/day, 365 days/year
- Full replacement cost estimate is $500 per fixture

Supplemental load reduction

Vending machine controls

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	2.1	$220	$57	$506	27.2%	3.8
Edmonton	2.1	$220	$47	$373	21.8%	4.7
Montréal	2.1	$220	$36	$230	15.7%	6.2

Measure-specific assumptions and notes:

- Equipment: occupancy sensing for vending machine
- Base case: no controls
- Measure case: occupancy sensing to control lights and compressor runtimes

Wall insulation, slab edge insulation, infiltration reduction

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	258.5	$125,092	$5,963	$6,555	4.4%	21.0
Edmonton	343.8	$129,412	$7,000	$25,116	5.4%	18.5
Montréal	309.9	$125,332	$4,975	-$15,503	3.1%	25.2

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)
- Montréal 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)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	65.9	$10,911	$1,676	$26,099	17.1%	6.5
Edmonton	62.6	$11,089	$1,416	$20,179	14.4%	7.8
Montréal	42.8	$10,624	$723	$5,339	7.3%	14.7

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)
- Montréal roof insulation upgraded from RSI-3.452 (R-19.6) to RSI-5.464 (R-31)

Windows

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	50.8	$53,037	$1,235	-$25,776	-0.3%	42.9
Edmonton	96.0	$53,525	$2,104	-$7,073	3.0%	25.4
Montréal	81.5	$51,058	$1,357	-$21,110	0.4%	37.6

Measure-specific assumptions and notes:

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

Heating and cooling resizing and replacement

Boilers

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	62.1	$3,437	$449	$2,237	11.7%	7.7
Edmonton	119.5	$3,437	$621	$4,412	18.1%	5.5
Montréal	89.6	$3,437	$915	$8,118	27.7%	3.8

Measure-specific assumptions and notes:

- Equipment: hot water boiler (gas-fired)
- Base case: 80% thermal efficiency
- Measure case: 97% thermal efficiency
- Full replacement cost estimate is $13,387

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	265.9	$45,932	$2,964	-$8,481	1.3%	15.5
Edmonton	414.9	$45,932	$3,218	-$5,278	2.4%	14.3
Montréal	450.7	$45,932	$4,985	$17,048	8.6%	9.2

Measure-specific assumptions and notes:

- Applicability: best suited for NECB 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	271.2	$8,320	$3,663	$37,958	45.8%	2.3
Edmonton	421.3	$8,320	$4,054	$42,897	50.6%	2.1
Montréal	444.1	$8,320	$5,190	$57,246	64.3%	1.6

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

PTAC – electric heating, occupancy control

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	184.3	$32,500	$5,068	$31,534	15.0%	6.4
Edmonton	300.0	$32,500	$6,733	$52,571	21.1%	4.8
Montréal	278.2	$32,500	$4,737	$27,351	13.7%	6.9

Measure-specific assumptions and notes:

- Equipment: occupancy controls for PTACs
- Base case: 11.3 EER, electric resistance heating, manual control
- Measure case: occupancy controls (setbacks) with 50% occupancy

Replace PTACs with packaged terminal heat pumps (PTHPs)

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	281.7	$13,000	$7,747	$84,875	61.5%	1.7
Edmonton	261.1	$13,000	$5,860	$61,040	46.9%	2.2
Montréal	260.9	$13,000	$4,443	$43,129	35.7%	2.9

Measure-specific assumptions and notes:

- Equipment: packaged terminal units for guest suites, 2.6 kW (9,000 BTU/hr), 65 units
- Base case: PTACs, 11.3 EER, electric resistance heating
- Measure case: PTHPs with COP of 3.6
- Full replacement cost estimate is $91,000

Low-flow showerheads

Example city	Annual savings estimate (GJ)	Incremental cost estimate	Annual energy cost savings	NPV estimate	IRR estimate	Incremental simple payback (yrs)
Vancouver	57.2	$975	$414	$4,251	44.2%	2.4
Edmonton	57.2	$975	$297	$2,782	31.8%	3.3
Montréal	57.2	$975	$584	$6,402	61.8%	1.7

Measure-specific assumptions and notes:

- Equipment: low-flow showerheads installed in 65 rooms
- Base case: 9.5 litres per minute
- Measure case: 4.7 litres per minute
- Full replacement cost estimate is $2,275

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	114.3	$5,290	$827	$5,153	15.1%	6.4
Edmonton	134.7	$5,290	$700	$3,557	12.0%	7.6
Montréal	124.4	$5,290	$1,270	$10,753	24.8%	4.2

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 hotels and motels in the form of a questionnaire. This tool complements ENERGY STAR Portfolio Manager by providing direction on how to set improvement goals based on your site energy use intensity (EUI); an ENERGY STAR score is not currently available for Canadian hotels and motels.

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

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

The **questionnaire** is organized by:

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

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

☐ **MAINTAIN**

○ **ADJUST**

◇ **INVEST**

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

PART 4

Instructions

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

Measure costing

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

ENERGY STAR PORTFOLIO MANAGER OUTPUTS

Site EUI: ______________________________

Source EUI: ______________________________

Median property EUI: ______________________________

TARGETS

Site EUI target: ______________________________

Hotels/Motels – Opportunity Questionnaire

EBCx

- ☐ Do the lighting and occupancy schedules match? [Pg. 8]
- ☐ Is the air handling system on a schedule? [Pg. 8]
- ☐ Are the zone temperature set points set back/forward during unoccupied hours? [Pg. 8]
- ☐ Does the air handling equipment have a properly functioning economizer to enable free cooling? [Pg. 9]
- ☐ Is the zone temperature deadband wide enough? [Pg. 9]
- ☐ Is the supply air temperature reset depending on outdoor conditions? [Pg. 9]
- ☐ Are the VAV zone dampers operating properly? [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. 18]
- ○ Have wall switches in enclosed rooms been replaced with occupancy/vacancy sensors? [Pg. 18]
- ◇ Have daylight sources and lighting control been installed? [Pg. 19]

Exterior / parking garage

- ○ Has exterior and parking lot lighting been replaced with LED lighting? [Pg. 19]
- ○ Has parking garage lighting been replaced with LED lamps? [Pg. 20]
- ◇ Have occupancy controls for parking garage lighting been added? [Pg. 20]

Supplemental load reduction

Power loads and equipment

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

Commercial kitchen

- ◇ Is ENERGY STAR equipment being used where applicable? [Pg. 23]
- ◇ Has DCV been installed? [Pg. 24]

Air distribution systems upgrade

- ○ Has heating been eliminated from front entrance vestibules? [Pg. 40]
- ○ Has CO control been added to parking garage exhaust? [Pg. 40]
- ◇ Is there a DCV system? [Pg. 39]
- ◇ Has the CV reheat, multi-zone, or dual-duct system been converted to a modern VAV system? [Pg. 39]
- ◇ Are fans and fan motors right-sized? [Pg. 39]
- ◇ Have VSDs been added to pumps and fans with variable loads? [Pg. 39]

Heating and cooling resizing and replacement

Central heating

- ○ Have heating pipes been insulated? [Pg. 44]
- ◇ Have existing boilers' control systems been replaced? [Pg. 43]
- ◇ Have flow-restricting valves been eliminated? [Pg. 44]
- ◇ Have pumps been replaced and right-sized? [Pg. 44]
- ◇ Are heating water pumps being controlled with VSDs? [Pg. 44]
- ◇ Have new burners been installed on existing boilers? [Pg. 45]
- ◇ Has a new condensing boiler been installed? [Pg. 45]
- ◇ Has a new hybrid boiler system been installed? [Pg. 46]
- ◇ Has a new heat pump system been installed? [Pg. 47]

- ☐ Is the HVAC system over-ventilating? [Pg. 10]
- ☐ Have supply and exhaust air imbalances been corrected? [Pg. 10]
- ☐ Does the humidification set point exceed minimum requirements? [Pg. 10]
- ☐ Is it possible to reduce the minimum flow set points at VAV boxes? [Pg. 10]
- ☐ Has missing or damaged duct insulation been repaired? [Pg. 10]
- ☐ Has the sealing around PTACs been assessed? [Pg. 10]
- ☐ Has missing or damaged pipe insulation been repaired? [Pg. 11]
- ☐ Has ductwork been sealed to prevent leakage? [Pg. 11]
- ☐ Are fan belts and pulleys operating at proper tension? [Pg. 11]
- ☐ Is there a heating water reset control strategy? [Pg. 11]
- ☐ Have the BAS sensors been calibrated recently? [Pg. 11]
- ☐ Have the PTAC coils been cleaned? [Pg. 11]

Walk-in coolers and freezers

- ○ Are fans turned off while doors are open? [Pg. 25]
- ○ Have electric defrost controls been modified for low-temperature freezers? [Pg. 26]
- ○ Are strip curtains being used? [Pg. 26]
- ○ Are compressors turned off when doors are open? [Pg. 26]
- ○ Have door closures been added? [Pg. 26]
- ○ Is air defrost being leveraged for medium-temperature coolers? [Pg. 26]
- ○ Has lighting been replaced with LED lamps? [Pg. 27]
- ◇ Has the insulation been upgraded? [Pg. 25]
- ◇ Have two-speed evaporator fans been installed? [Pg. 25]
- ◇ Have evaporator fan motors been replaced with electronically commutated motors? [Pg. 25]
- ◇ Has a free cooling system been installed? [Pg. 26]

Commercial laundry

- ◇ Have high-efficiency dryers been installed? [Pg. 27]
- ◇ Have high-efficiency washers been installed? [Pg. 27]
- ◇ Has dryer exhaust heat recovery been added? [Pg. 27]

- ◇ Have steam humidifiers been replaced with atomizing type? [Pg. 40]
- ◇ Have existing air filters been replaced with electronic air cleaners? [Pg. 40]

Rooftop units

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

Domestic hot water

- ○ Have low-flow aerators and showerheads been installed? [Pg. 56]
- ○ Have domestic hot water pipes been insulated? [Pg. 56]
- ◇ Is water being preheated with solar thermal collectors? [Pg. 56]
- ◇ Have hot water boilers/ heaters been replaced with high-efficiency units? [Pg. 58]

Hotels/Motels – Opportunity Questionnaire (continued)

EBCx	Lighting upgrades	Supplemental load reduction	Air distribution systems upgrade	Heating and cooling resizing and replacement
		Envelope ○ Have infiltration issues been addressed? [Pg. 29] ◇ Has an air barrier been added or improved? [Pg. 31] ◇ Do the roof and wall insulation levels meet NECB requirements? [Pg. 32] ◇ Have the windows and doors been upgraded? [Pg. 32] ◇ Does the building have a “cool roof”? [Pg. 33] ◇ Has an entrance vestibule been added? [Pg. 33]		**Swimming pools and spas** ☐ Have ventilation flow rates been minimized? [Pg. 60] ☐ Have humidity levels been optimized? [Pg. 60] ☐ Is the pool temperature maintained at 26 °C? [Pg. 60] ○ Are pool covers being used during unoccupied hours? [Pg. 59] ◇ Has a dehumidification system with heat recovery been installed? [Pg. 60] ◇ Have filter pumps been replaced with high-efficiency units? [Pg. 60] ◇ Have filter pumps been replaced with variable or two-speed pumps? [Pg. 61] ◇ Has a solar thermal system for pool heating been installed? [Pg. 61]

Guest room measures

Guest rooms are the largest space type in hotels and motels and account for the majority of their energy consumption. Measures include:

Lighting

- ○ Have existing fixtures or lamps been replaced with LED lamps? [Pg. 18]
- ○ Have incandescent Exit signs been replaced with LED signs? [Pg. 18]
- ◇ Have suite occupancy controls for lighting been installed? [Pg. 19]

Supplemental loads

- ◇ Have suite occupancy controls for plug loads been installed? [Pg. 22]

Heating and cooling

- ◇ Have suite occupancy controls for PTACs been installed? [Pg. 53]
- ◇ Is PTAC control integrated with the central BAS? [Pg. 54]
- ◇ Have PTACs been replaced with high-efficiency models? [Pg. 54]
- ◇ Have PTACs been replaced with central plant-supported systems? [Pg. 55]