HEALTHY HIGH-RISE

A Guide to Innovation in the Design and Construction of High-Rise Residential Buildings

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ENHANCING ENERGY PERFORMANCE

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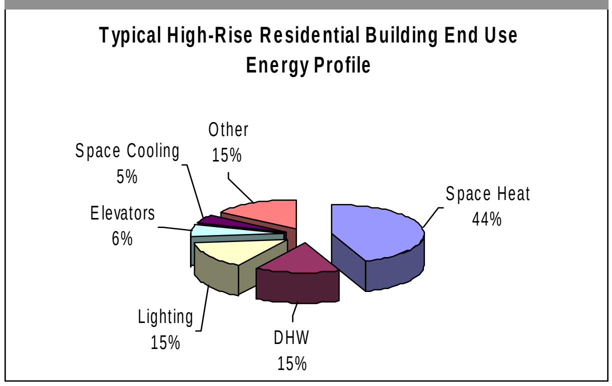
Highrise residential buildings represent 10% of all dwelling units in Canada and are major consumers of energy. On a floor area basis, they consume more energy than single family dwellings - even though the highrise unit has much less exposed exterior surface. And when compared to the leading edge Advanced House standards for energy consumption, multi-unit residential buildings consume three times the amount of energy per unit of floor area.

Higher energy consumption in high-rise residential buildings reflects the fact that envelopes are not as airtight, nor as thermally efficient. Air leakage rates in high-rise buildings are significantly higher than those found in low-rise buildings. Typically, highrise apartment buildings have lower insulation levels, poorer windows, and more thermal bridging than lowrise residential buildings. As well, their ventilation systems generally operate without the benefit of heat recovery.

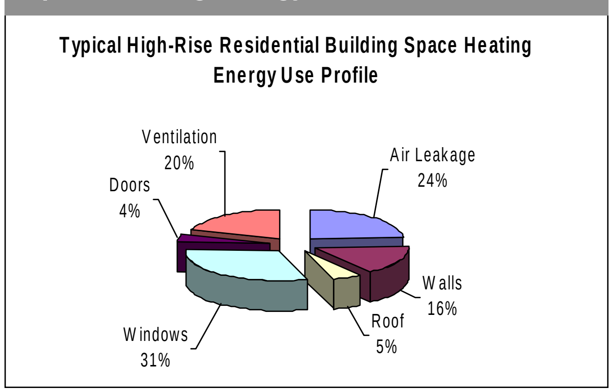
Advances to space and domestic hot water heating and distribution systems in high-rise buildings have not matched the efficiency improvements in low-rise residential buildings. Newer approaches

Typical High-Rise Residential Building End Use Energy Profile



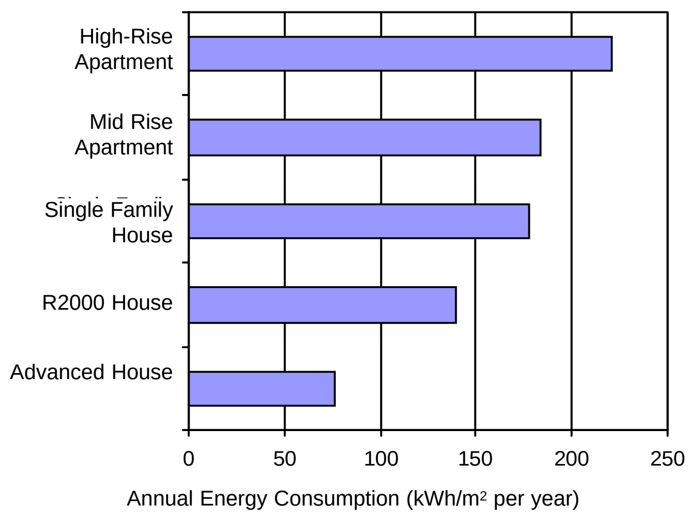
Source: Energy Audits of High-Rise Residential Buildings, CMHC, 1996

Typical High-Rise Residential Building Space Heating Energy Profile



Source: Energy Audits of High-Rise Residential Buildings, CMHC, 1996

Typical Annual Energy Consumption of Canadian Buildings



to reducing energy consumption while improving air quality, such as with the use of heat recovery ventilation systems, are beginning to be accepted by the high-rise industry.

High-rise buildings also have high electrical demands, specifically for corridor, parking garage, and exterior lighting requirements, as well as for motors for elevators, pumps, and fans.

A number of advances in energy efficiency technologies are available to improve the performance of highrise residential buildings:

- increased air tightness and reduction of thermal bridging of building envelopes,
- air movement control strategies,
- high performance windows,
- improved thermal insulation,
- higher efficiency lighting systems,
- energy efficient appliances and motors,
- advanced heating/cooling systems e.g. in-suite heat pumps/HRV,
- improved control systems,
- improved suite ventilation systems,
- heat recovery (air and water),
- improved elevator technologies,
- water conservation (see Environmental Performance: Water).

Active promotion of building occupant participation in improved energy performance is also vital to reducing energy use.

Several existing standards suggest minimum levels of energy performance for high-rise residential buildings. ASHRAE Standard 90.1-1999, “Energy Standard for Buildings Except Low-Rise Residential Buildings” is recognised as a minimum standard for energy performance of high-rise residential buildings.

The Model National Energy Code for Buildings (MNECB) contains requirements that are similar to ASHRAE Standard 90.1-1999. However, it references Canadian standards and regulations in metric (SI) units. The MNECB sets minimum standards of construction for features that affect energy efficiency. Requirements are based on cost effectiveness, taking into account regional climate, energy costs, and construction costs.

Reduced energy consumption leads to direct cost savings for building owners and occupants. At the same time, energy efficient buildings are generally more durable, comfortable, and healthy than less energy efficient buildings. Consideration of maintenance issues at the design stage can lead to improved operating costs. Less maintenance, enhanced occupant satisfaction, lower turnover rates and fewer occupant call-backs are a major incentive for the owners.

BUILDING ENVELOPE

Related Topics

Air Barriers
Exterior Insulation and Finish System (EIFS)
Space Heating and Air Conditioning
Alternative Energy Supply Systems
Mechanical Ventilation
Site Planning
Landscape Practices
Occupant Comfort - Noise

THE ISSUES

The building envelope plays a critical role in the energy performance of high-rise residential buildings. Designers can reduce building envelope related energy losses by reducing air leakage through the envelope, using high performance windows, increasing insulation levels, and minimising thermal bridging.

Poorly performing thermal envelopes can result in:

- high utility costs to the building occupants or owner (depending on the metering strategy),
- occupant discomfort due to cold surfaces, drafts, radiant heat losses, overheating and movement of odours,
- deterioration of interior finishes and exterior materials from condensation,
- poor indoor air quality from condensation related mold growth.

Poor performance is commonly a function of:

- a lack of continuity of the air barrier system,
- inadequate thermal resistance of envelope components,
- thermal bridging to the outside (eg. via floor slabs, shear walls, steel studs),
- selection of materials and components (shelf angles, balconies and foundations) only considering the lowest cost,
- poor installation practices and lack of quality control (including commissioning).

Good thermal envelope design practice should provide:

- low air leakage,
- higher thermal resistance of exterior envelope components,
- high performance glazing systems,
- elimination of thermal bridging,
- reduced summertime solar heat gains and winter heat loss.

Achieving good design is possible by considering the importance of the following key elements:

- Windows & Solar Control
- Air Leakage
- Insulation Systems
- Thermal Bridging

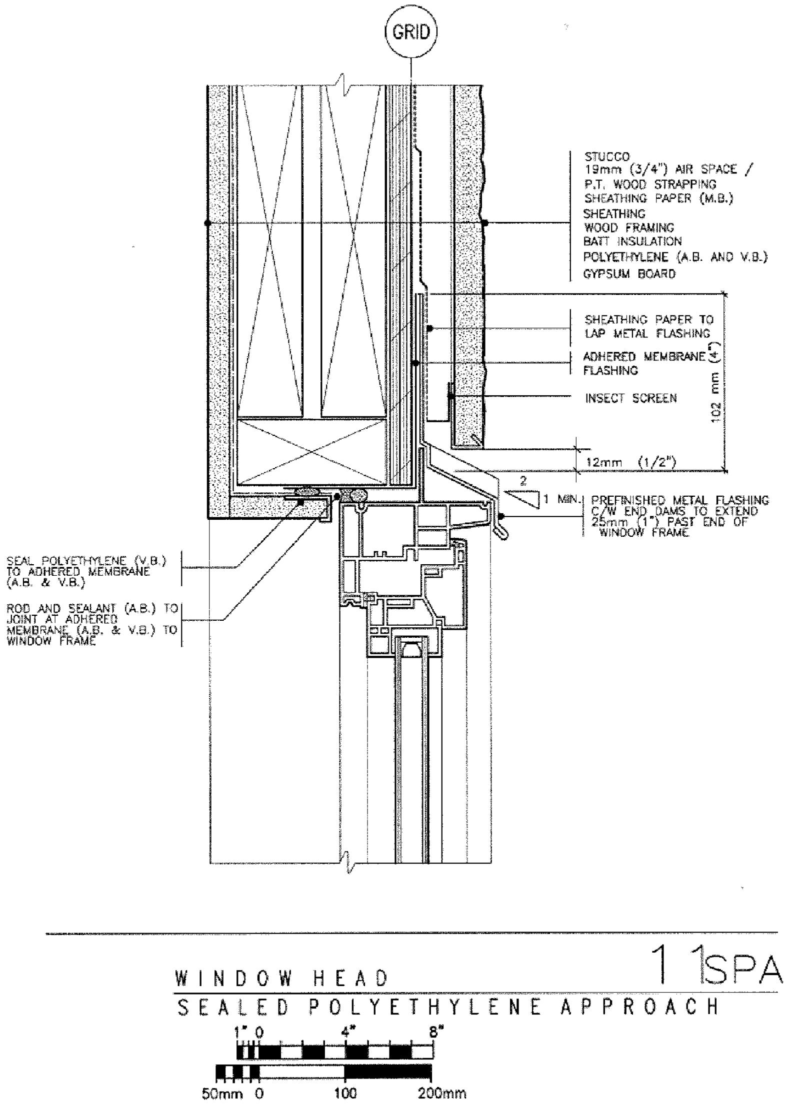
DESIGN CONSIDERATIONS

Windows and Solar Control
Heat loss through windows is one of the most significant components of space heating load in high rise residential buildings. The typical R value of a window is less than one tenth that of insulated walls. Yet in many cases, windows represent the largest component of the wall area.

New energy efficient windows save heating and cooling energy costs, reduce window condensation and improve occupant comfort as well. Suites will be much more comfortable year-round due to reduced discomfort from radiant heat loss to cold window surfaces, and a reduction in cold drafts.

Better insulated windows reduce or eliminate condensation which can obscure views, cause damage to sills, finishes and walls, reduce the life of glazing seals, and cause mold related health problems. Good window design can also reduce overheating in the summer, leading to reduced energy consumption for cooling and heating and improved occupant comfort.

Window Head



In addition to satisfying the requirement of controlling conductive heat loss, windows must also control moisture flows, infiltration air flow, solar heat gains, and natural ventilation airflow. Improved window performance also requires proper installation to ensure that the window-wall interface keeps out water and maintains the integrity of the walls air barrier system. Poor installation will undermine the energy and comfort performance improvements of even the best windows.

High thermal performance windows have:

- low-emissivity glazing,
- inert gas fills between window panes,
- advanced framing materials and designs and
- insulating spacers.

Window size and solar and thermal characteristics should be specified by wall orientation to achieve the optimum energy efficiency balance between maximised winter solar gains, minimised winter heat loss, and minimised summer solar gains. For residential buildings in Canada this usually means maximising the insulation value of windows in all orientations. To reduce summer heat gains, south and particularly west facing windows can be reduced in size. Coloured glazing can be used and external shading devices can also be employed.

When high performance windows are analysed on a life cycle basis, the incremental cost of adding low-e coatings and argon fill to double pane windows is easily offset by energy savings in most regions. Low-e coatings, argon fill and casement style windows (instead of sliding because of lower air leakage) are generally found to be the features with the greatest energy efficiency benefit for cost. The true value of high performance windows should also consider the reduced maintenance costs, reduced mechanical equipment sizes, and the value of improved occupant comfort, ease of use, security, and health implications.

Several other window design and installation issues affect building energy efficiency. Air leakage resistance should be appropriately specified according to the CAN/CSA-A440 Standard. The location of the window in terms of height and wind speed exposure, and reduce energy losses due to air leakage must be considered. The window must also be properly sealed into the window opening to maintain the air leakage resistance of the window to wall interface.

Air conditioning requirements can be reduced by maximising natural ventilation airflow through the design and placement of windows. To maximise single sided natural ventilation in apartments, the openable area of windows should be as large as possible. Window opening areas should be separated by as much height as possible to take advantage of room stack effect (ie. tall windows with openings at the top and bottom). Windows should also be located to take maximum advantage of any cross ventilation possibilities. Solar protective glazing and external solar shading devices will also reduce solar gains and resulting cooling requirements.

Air Leakage

Next to heat losses through windows, the greatest contributor to space heating energy use in most high rise residential buildings is the energy required to heat unintentional air leakage into the building. Stack, wind, and the ventilation system induce pressure differences between the inside and outside of the building. These pressure differences cause outside air leakage into the building. Energy is then required to heat or cool incoming air.

Air leakage also causes:

- occupant discomfort associated with cold drafts and heat stratification (ie. hot air rising to upper floors and cold air at lower floors causes upper floor occupants to compensate by opening their windows and lower floor occupants to turn up their heat),
- movement of odours from suite to suite,
- moisture-related building envelope deterioration and health related concerns,
- poor indoor air quality,
- difficulty designing effective smoke control systems.

Air leakage can reverse the intended flow of ventilation air resulting in under-ventilation of some suites in a building and over-ventilation of others. To avoid these problems, a well designed building should be as airtight as possible, with mechanical ventilation systems supplying ventilation air independently of air leakage (build tight, ventilate right).

Methods for improving the air tightness of walls and windows of the building are found in the Enhancing Envelope Design section of this document. Particular attention should also be made to sealing intentional or unintentional vertical shafts within the building. Air leakage contributions to stack induced air movement through elevator and stairway shafts, mechanical, plumbing and electrical shafts, garbage chutes, and vertical ventilation and exhaust ductwork.

All vertical shafts should be designed to minimise potential airflow with the rest of the building at each floor level, with particular attention paid to locations near the top and bottom of each shaft. Maximum allowable airflow leakage rates should be specified for all doors, windows, and dampers connected to vertical shafts.

Elevator doors should be tight fitting, with potential airflow openings minimised at the top of elevator shafts. Doors, windows and walls in elevator penthouses should be well sealed. Alternative elevator systems are available for low rise buildings (up to 7 stories) that eliminate the need for elevator machine rooms. This can remove a major air leakage source at the roof. Automatic dampers are needed to shut off airflow though corridor supply ducts and vertical exhaust systems when fans are off. Smoke vents in vertical shafts should be provided with automatic dampers with smoke sensors. Plumbing, electrical, and ductwork penetrations through floors should be inspected to ensure that they are well sealed. Garbage chute doors and doors to chute rooms should also be gasketed.

Understanding of air leakage patterns in high rise apartment buildings has progressed to the point where air tightness specialists can be retained to develop air leakage specifications, train contractors, inspect and test construction, and certify compliance.

Insulation Systems

Canadian building codes specify minimum construction standards that mainly address only health and safety issues. Increased insulation levels above code can greatly enhance energy, heating and cooling performance.

Residents will also be more comfortable when radiant heat loss is reduced. Insulation is cheap and permanent with no maintenance cost. An investment in insulation will pay off for the life of the building in energy cost savings. It is also a buffer against future fuel price increases.

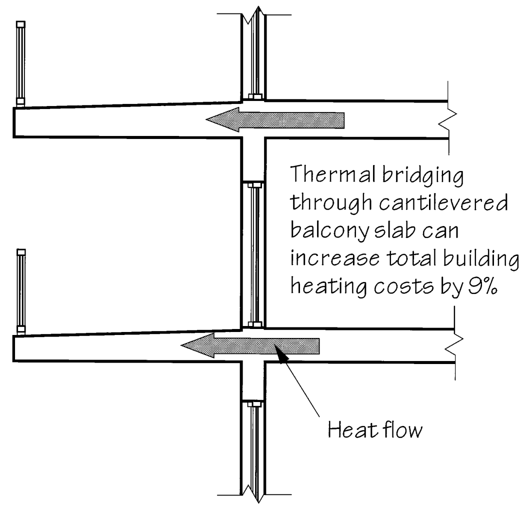
Typical insulation levels in Canadian high-rise buildings range from RSI 1.5 to 2.1 (R8 to 12) in walls, and RSI 3.5 (R20) in roofs. These insulation levels are below the levels commonly found in newer low-rise buildings, and are significantly below the levels recommended in the Model National Energy Code for Buildings. The Model National Energy Code for buildings requires insulation levels ranging from RSI 1.5 to 3.7 (R8 to R20) in walls, and RSI 5 to 10 (R28 to 57) in roofs. Higher insulation levels than these will generally provide diminishing returns.

A variety of exterior insulation systems have gained wide-spread market acceptance. The choice of material can be affected by cost, resistance to moisture damage, environmental impacts (off-gassing potential and environmental impacts from manufacturing), combustibility requirements, resistance to insect damage, and thickness requirements. Exterior rigid insulating materials have RSI values ranging from RSI 0.028/mm (R4/in) through to RSI0.056/mm (R8/in). CFC-free insulation materials reduce negative environmental impacts.

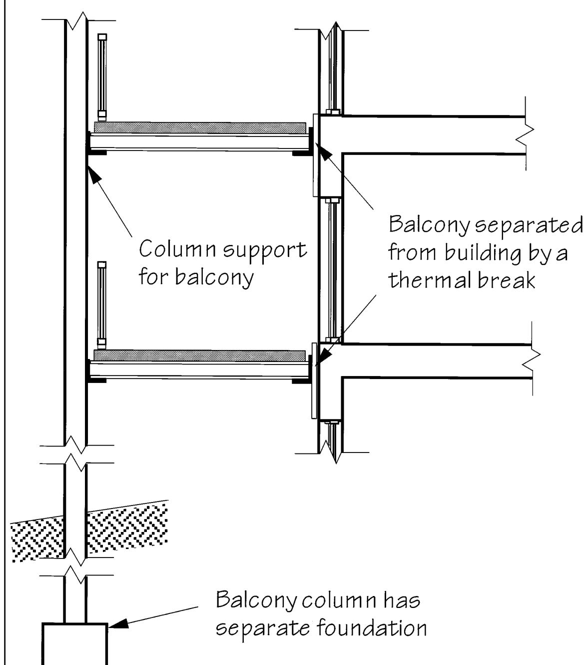
Insulation can generally be placed on the outside of the wall system, in the wall system, or on the interior of the wall system. The placement of insulation on the exterior of the backup wall, outside of the air barrier has the advantages:

- a significant reduction in thermal bridging,
- physical protection of the air barrier,
- movement of the cold condensing surface to the outside of the backup wall and air barrier. This allows any condensation to run off through a drainage cavity rather than remaining within the wall where it can reduce thermal performance and create other moisture related problems.

Minimizing Thermal Bridging at Balcony Slabs



Thermal bridging at cantilevered slab



A drawback of this approach is the reduction in buildable floor area allowed by jurisdictions that use outside building dimensions to calculate maximum allowable floor space ratios.

Regardless of location, the insulation should be installed in a manner which avoids excessive compression and reduces thermal bridging, and gaps and air spaces. Mechanical fastening of rigid insulation products should be designed to prevent excessive compression that reduces thermal performance, minimise the effects of thermal bridging, and allow for thermal movement. Installation of insulation should ensure minimisation of gaps and spaces that can allow convective loops and reduce thermal performance. To prevent air circulation, rigid insulation should be fastened in continuous contact with the airtight plane, preventing air circulation around the insulation. Where gaps are required between sheets of rigid insulation to allow for thermal expansion or structural movement, the gaps should be filled with bat insulation.

Designers must also consider exposure to moisture and high temperatures when specifying roof insulation products. To reduce thermal bridging in rigid insulation roofing systems, insulation boards must be tightly installed to prevent roof ballast from working its way between sheets. Shiplap joints represent a means of better ensuring continuity of the insulation coverage.

Thermal Bridging

Attention is too often focused on the main insulating components of exterior walls without considering that localised thermal bridging can significantly increase the heat loss. Thermal bridges are locations of minimal thermal resistance that allow heat to flow directly to the exterior. Thermal bridges can also act as radiant fins such as with non thermally broken balcony slabs. In all cases they have a significant effect on building heat loss. Balcony slabs, shear walls, spandrel beams, window frames, shelf angles, and parapet walls all represent areas which provide minimal resistance to heat flow between the interior of the building and the exterior. Thermal bridging at these locations can cause frosting and condensation on interior finishes, and discomfort from cold walls and cold floors adjacent to balconies.

Higher performance building envelopes eliminate potential thermal bridging problems. Exterior applied insulation can significantly reduce many thermal bridging problems found in exterior walls since it can cover locations such as floor slabs that cannot be insulated from inside the wall or building.

Balcony slabs represent a particularly weak point in the thermal envelope, providing a highly conductive path from the interior to the exterior, where heat is dispersed over a broad area. Replacing balconies with inset sunspaces is one way to reduce thermal bridging across the slab and enhance passive solar gains (although they may introduce condensation problems if not detailed properly). Designers could also consider thermally detaching the balcony slab, replacing cantileverd balconies with light-weight pre-cast slabs supported with an independent structure and short ledger supports.

When making changes to thermal bridging details, care must be taken to ensure that waterproofing is not compromised.

RETROFIT OPPORTUNITIES

Building envelope retrofit measures can significantly improve the energy efficiency of existing high rise residential buildings. Major envelope energy efficiency retrofit measures are generally expensive and can have long payback periods when their full capital costs are compared to energy cost savings. However, when these measures are implemented when the building is being renovated for other reasons, or during repair or replacement work, then the incremental cost of energy improvements can often be recovered quickly with energy cost savings. Because building envelope improvements will reduce heating and cooling system loads, the replacement of heating and cooling equipment should be carried out after envelope retrofit measures if possible. Reduced capital costs and increased energy cost savings will result from the installation of smaller, more efficient equipment.

The following are a number of envelope retrofit measures that can be carried out during renovation or equipment replacement / repair:

1 **Insulate when replacing roofing** –Two common roofing systems used for high rise apartment buildings are Built-up Roofs and Inverted Roofs. Insulation can be easily installed with either system as part of roof membrane replacement. The incremental cost of added insulation can be recovered quickly from energy cost savings, especially for roofs with no insulation. Additional benefits include reduced cooing costs and cooler summertime temperatures in top floor suites.

2 **Upgrade to high performance windows during window replacement**–During window replacement projects windows can be upgraded to high performance windows such as double glazed windows with low e coatings.

3 **Insulate and air seal when repairing interior walls**–When wall cavities are exposed, batt insulation and a new air barrier can be installed. If interior wall surfaces are not removed, Fibreglass or cellulose insulation can be blown into wall cavities. Interior walls can be air sealed with special vapour barrier paint applied to the wall surface.

4 **Insulate and air seal when repairing exterior walls -** The exterior surface of walls can be insulated and an effective air barrier added at low incremental cost during extensive repair or replacement of the exterior cladding system. While in most cases cladding will be removed to make underlying repairs, overcladding,-where an airtight air barrier system and rigid board exterior insulation are added over top of existing cladding systems is a possibility in some cases (eg. on walls that are in good condition but are being reclad to match upgrades to adjacent deteriorated walls). Rainscreen type EIFS systems use insulated panels that will upgrade insulation levels when used to replace existing cladding.

5 **Replace exterior cladding with “Solarwall” type cladding systems when repairing exterior walls -** Existing cladding systems can be replaced with commercially available active solar cladding systems that preheat ventilation air and reduce ventilation air heating costs. (see Alternative Energy Supply Systems and Case Studies).

6 **Insulate floors over unheated spaces**–The underside of slab floors exposed to unheated garages and cantilevered floors over unheated spaces can be insulated with rigid or blown insulation.

7 **Seal exterior wall air leakage as part of a preventative maintenance program**–The inside of exterior walls can be sealed with foam or caulking around electrical boxes, window frames, floor to wall junctions, wall to wall junctions, behind baseboard heaters, and around air conditioner sleeves. Cracks on the outside of exterior walls can be sealed around doors, windows, and other exterior joints, taking care not to compromise the function of rainscreen or drainage cavity systems. Because air sealing will reduce air infiltration, care must be taken to ensure that ventilation systems will supply sufficient ventilation for indoor air quality and remove moisture to avoid high humidity levels.

8 **Seal window, door, and vertical shaft air leakage -** Window weather-stripping, which can wear out in as little as 5 or 6 years, can be replaced or upgraded and at the same time worn or shrinking gaskets and other window repairs can be made. Weather-stripping can be upgraded on exterior lobby, entrance, stairwell, balcony, service, penthouse and overhead doors. At the same time doors should be adjusted so that they close properly and door closers installed if not already provided. Proper sealing of entrance, stairway and garbage room doors on the ground level is particularly important due to inward airflow as a result of stack effect in tall buildings. Holes in wall, floors, and wall/roof

joints should be sealed in elevator and mechanical penthouses. Automatic dampers should be installed to shut off airflow though corridor supply ducts and vertical exhaust systems when fans are off. Smoke relief louvers in elevator shafts should be replaced with automatic dampers with smoke sensors. Plumbing, electrical, and ductwork penetrations through floors and to underground garages should be well sealed.

Sources of Information

- *The High-Rise Residential Construction Guide 1995*, Ontario New Home Warranty Program.
- *Energy And Water Efficiency in Multi Unit Residential Buildings*, Technical Manual, CMHC 1999.
- CAN/CSA –A440-98 *Windows*, Canadian Standards Association.
- CAN/CSA-A440-2 *Energy Performance of Windows and Other Fenestration Systems*, Canadian Standards Association.
- *Fundamentals*, American Society of Heating Refigerating and Air Conditioning Engineers Inc. (ASHRAE).
- ASHRAE Standard 90.1-1999, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, American Society of Heating Refigerating and Air Conditioning Engineers Inc. (ASHRAE)
- *Model National Energy Code for Buildings*, National Research Council of Canada.

SPACE HEATING & AIR CONDITIONING

Related Topics

Air Barriers
Exterior Insulation and Finish System (EIFS)
Building Envelope
Other Systems
Alternative Energy Supply Systems
Mechanical Ventilation
Landscape Practices
Occupant Comfort - Noise

THE ISSUES

Current heating and cooling systems in high-rise buildings can fail to perform satisfactorily, and comfort related problems voiced by occupants are common. Problems include:

- poor heating and cooling distribution in the building (overheating on upper floors, underheating on lower floors),
- poor heating and cooling temperature control within suites
- uneven temperatures within suites,
- complaints of warm stuffy corridors,
- cool corner suites,
- high energy costs,
- noise from equipment and airflow.

These problems are usually a function of building envelope-related wind and stack effect induced airflow, or the sizing, control, installation, or maintenance of mechanical systems.

The design of heating/cooling systems should:

- optimize climatic benefits - taking advantage of renewable energy sources,
- provide high levels of thermal comfort within buildings and suites,
- provide heating/cooling in an energy efficient non-polluting manner,
- allow for occupant control,
- be easy to use and maintain,
- be capable of providing part and peak loads at optimum efficiency
- balance first time costs with operating and maintenance costs over the expected lifetime of the equipment,
- provide flexibility in use of fuel to allow for energy supply and cost security,
- promote accountable energy use through the use of individual metering.

While the choice of heating and cooling systems will be influenced by the type of building being designed and the target market expectations, the design of heating/cooling systems should reflect:

- proper sizing of equipment based on building energy simulations
- distribution system zoning based on location and orientation within the building ,
- an understanding of good engineering practice such as described in the ASHRAE Handbooks and Standards, the HRA Digest, etc.,
- adherence to comprehensive commissioning, operating and maintenance strategies.

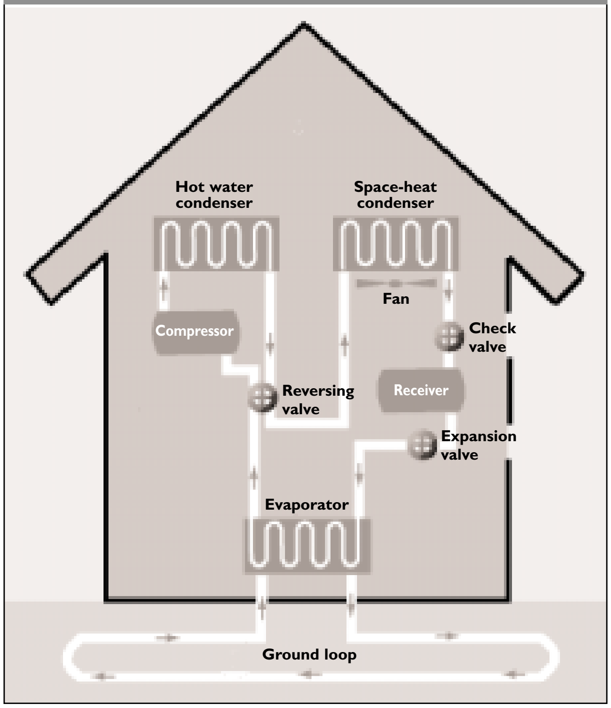
Designers and engineers should be aware of the issues and options concerning:

- Integrated Design Process
- Electric Heating Systems
- Natural Gas Heating
- HVAC Distribution Systems

DESIGN CONSIDERATIONS

Integrated Design Process
The design of the heating and cooling systems must be part of an integrated building design process that considers how the interaction between building components affects the overall building performance. When part of an integrated design approach, significant capital cost savings for HVAC systems are possible. These cost savings can often easily offset any extra costs associated with other energy efficiency improvements.

Diagram of a closed-loop ground source heat pump



For example, better building envelope design can reduce heating loads for the building. Reduced heating loads and more efficient heating equipment can reduce the size of heating and distribution equipment. Reducing the size of this equipment can significantly reduce capital costs and allow more rentable space within the building.

Likewise, summer cooling loads can be reduced by:

- using solar protective glazing and external shading devices,
- more dayighting can reduce heat gains from lighting (if care is taken to prevent solar overheating),
- building envelopes that maximise natural ventilation airflow will lower cooling loads.

Smaller cooling loads and more efficient cooling equipment can significantly reduce the size and capital cost of cooling and distribution equipment.

Electric Heating Systems

Electric baseboard systems are the predominant heating choice in many parts of the country, due to the their low capital cost. The high cost of electricity in most areas, is a concern. There are also negative environmental impacts of nuclear, fossil fuel, and large-scale hydro-generated electricity.

Heat pumps offer a much more efficient alternative to electric resistance heat. They can be very cost effective when considering the cost of installing air conditioning. Heat pumps transfer the heat from the outside air or ground into the building in winter. In summer, they transfer the heat out of the building, using the same principle as a refrigerator. There is a net gain in heat energy supplied over electrical energy used to drive the system. Typical air-cooled heat pumps have mild temperature coefficient of performance (COP) ratings greater than 3.0, using less than one third of the energy consumption of electric resistance heating.

Air source heat pumps are well suited to moderate climates, but they do not operate efficiently in climates where the outdoor air temperature drops below about -10C (these locations require some auxillary heat sources in cold weather). Ground source heat pumps maintain their efficiency all year round, due to more uniform ground temperatures. Despite high initial capital costs, ground source heat pumps for large apartment buildings recover these costs quickly in energy savings.

Natural Gas Heating Systems

Where available, natural gas has been used as a fuel of choice for central heating and service hot water in high-rise buildings. In some areas of the country, recent trends have been toward suite-based space conditioning systems where each suite is individually metered and supplied with its own heating, cooling and domestic hot water (DHW) system. Increases in natural gas costs point out the disadvantage of dependence on one fuel and the advantage of greater fuel flexibility.

Integrated space heating and DHW systems can be more energy efficient than individual space heat and DHW systems. They become more suitable when heating/cooling loads of suites are reduced through improved integrated building design.

The efficiency of central systems continues to improve. High efficiency boilers are readily available and have a proven track record of operating efficiently (as high as 92% for condensing gas boilers). Increasingly, designers are specifying a multiple boiler system for a better matching of the required load to the capacity of the equipment.

HVAC Distribution Systems

HVAC systems can be central or modular in design. Central systems, such as 2 or 4 pipe hydronic systems, have centralised heating and cooling equipment with local fan coil or other distribution units in each suite. Modular systems have heating and cooling equipment located within each suite e.g. heat pumps in each suite.

Both have their advantages and disadvantages. Modular systems provide greater independence of individual suites, and energy consumption is easier to meter. Central systems can reduce energy costs by using improved micro-processor controls, variable speed drives, and energy management control systems. They also provide greater fuel flexibility, have a centralised point of maintenance, and allow greater control by building management.

RETROFIT OPPORTUNITIES

The energy consumption and costs of operating heating and cooling equipment can be reduced with retrofit measures that improve the efficiency of existing equipment, replace equipment with new high efficiency equipment, or involve fuel switching. The payback period for retrofit measures will be reduced when equipment is modified during routine maintenance or replaced with high efficiency equipment during major renovation projects or when the equipment is being replaced at the end of its useful life.

1 Replace gas fired boilers with high efficiency units–Replacement gas fired boilers are available with Annual Fuel Utilization Efficiencies (AFUE) greater than 90% compared to 65% for older naturally aspirating units.

2 Insulate boilers and hot water heating piping to reduce heat losses and improve heat delivery to suites.

3 Seal and insulate warm air ducts in unheated spaces such as in the roof, rooftop penthouse, or unheated garages.

4 Calibrate the hot water reset temperature controller in buildings with hot water heating –Controllers that reset the water temperature upward as the outdoor temperature falls should be calibrated so that the system temperature is just hot enough to meet heating requirements.

5 Replace or resize boiler make-up grilles to improve combustion or dilution airflow in atmospherically vented boilers.

6 Install timeclocks to reduce operation of local exhaust fans in laundry, recreation, and storage rooms. The times that local exhaust fan operation should be matched to the usage patterns of the space.

7 Reduce heated garage temperature - The operating temperature of heated garages should be reduced to 5°C. Thermostats may have to be replaced if they do not have a range of temperature control as low as 5°C. If garage temperatures are maintained at elevated levels to avoid freezing pipes and cold floors above the garage, insulation and self regulating tracing cable can solve these problems for a fraction of the cost of energy to heat the garage.

8 Shut down ventilation fans serving unused garage areas to reduce fan energy and heating requirements for makeup air. Do not switch off exhaust fans on the lowest level of multi level garages since carbon monoxide collects there because it is heavier than air.

9 Convert from higher cost heating fuel to lower cost fuel - The most typical conversion is from electricity or oil to natural gas, with work performed during replacement or upgrading of heating equipment.

10 Indoor swimming pool dehumidification– Installation of a dehumidification system on existing heating and ventilation systems will remove heat and moisture from the air and return it to the pool or enclosure. Much lower exhaust rates can then be used to prevent moisture damage to the pool enclosure. Pool enclosure heating and water heating requirements are both significantly reduced.

Sources of Information

- *Mechanical and Electrical Systems in Apartments and Multi-Suite Buildings, A Practitioners Guide,* CMHC, 1999.
- *The High-Rise Residential Construction Guide 1995*, Ontario New Home Warranty Program.
- *Energy And Water Efficiency in Multi-Unit Residential Buildings*, Technical Manual, CMHC, 2000. Tip of the Week @ www.cmhc-schl.gc.ca/en/imquaf/himu/himu/indexw.cfm
- *Fundamentals*, American Society of Heating Refigerating and Air Conditioning Engineers Inc. (ASHRAE).
- ASHRAE Standard 90.1-1999, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, American Society of Heating Refigerating and Air Conditioning Engineers Inc. (ASHRAE)
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OTHER SYSTEMS

Related Topics

Space Heating and Air Conditioning
Lighting and Appliances
Mechanical Ventilation

Control Systems

Energy management control systems (EMCS) can significantly enhance the operating performance of central systems by providing effective zone control, matching supply with demand, and optimising equipment efficiencies. EMCS can also allow for more accurate monitoring of energy use in the building. These systems can be designed to integrate any of the following energy saving functions:

- time of day energy use (eg. controlling lights, corridor ventilation fans, central exhaust fans and block heaters according to optimised time schedules),
- temperature setback and zone controls (turning down heating or cooling at night, shutting off zones when not in use),
- temperature/time optimisation (monitoring exterior/interior temperatures to control HVAC operation),
- supply temperature reset (adjusting supply air or water temperature to meet building needs),
- economiser cycles (using outside air for free cooling),
- demand limit (shedding large loads at peak electric consumption times to control monthly peak electrical demand),
- duty cycling (controlling equipment on/off),
- humidity control,
- air quality control.

To be effective, these control systems need qualified personnel to operate them.

Individual Suite Metering

In many rental apartment buildings, central heating and cooling equipment is used with no metering or cost allocation to individual units. Research has shown that metering of individual suites or using energy cost allocation techniques are effective ways to influence the behaviour of multi unit residential building tenants, typically reducing energy use by 15% or more[1]. While energy consumption is usually lowered, metering costs and higher residential utility rates (over commercial rates) in some cases reduce energy cost benefits to individuals. While metering of energy consumption to individual units is one method, variations in exposed surface area, wind and stack effects, and so on, cause large variations in energy consumption of individual units and may therefore be inequitable. Another choice is energy cost allocation systems that monitor and allocate costs based on the set point of individual dwelling unit thermostats. When residents are aware of consumption and cost, and realise that they can save money with a lower average set point, they keep the windows closed and turn down their thermostats.

Metering or energy cost allocation for hot water consumption in multi-unit residential buildings has a similar effect on hot water consumption. Thermal energy meters are readily available that can meter the energy of hot water space and DHW consumption. They can also report consumption automatically to a central monitoring system.

Metering of electrical consumption in all multi-unit residential buildings is a relatively simple task that could be used to reduce energy consumption through behavioural change, and is particularly important for electrically-heated buildings.

Motors

Energy efficient motors are widely available. The table below summaries ttheir efficiency compared to conventional motors.

Energy Efficiency of Motors

Motors Type	Efficiency
Electrically Comutated	70-80%
Permanent Split Capacitor	45%
Conventional Split Phase AC	30-35%

Pumps and fans that have long run times or are operated continuously for water circulation or ventilation should always use high efficiency motors. Equipment that runs during both heating and cooling seasons will also benefit greatly from high efficiency motors. Variable speed drives for pumps and fans can reduce energy consumption by as much as 35%when compared to single speed systems.

While elevators are not a major contributor to energy use in a high-rise building, significant improvements are available. More efficient motors and control systems can reduce their total consumption by 40%. Technologies are also available that place the motors within the elevator shaft, eliminating the requirement for a mechanical penthouse and their the associated air-leakage problems.

Auxiliary Electric Heaters

Garage ramp heaters and exterior block heaters are large energy users. Snow/ice and temperature sensing controls should be used on garage ramp heaters to ensure that they only operate when required. Snow melting, using sub-slab piped hot water from boilers, can be much more cost effective and reliable than electric resistance heaters. A better alternative would be level access or covered ramps so that ramp heaters are not needed.

Timers and thermostat controls can reduce energy use by block heaters. Thermostats should control block heaters so that they only operate at temperatures below -9°C. Since block heaters are only needed for 3 to 4 hours before the vehicle is started, timers can be set for block heaters to start as required by tenants.

Domestic Hot Water

Domestic hot water (DHW) energy use can be reduced through installation of low flow shower and sink fixtures. Low flow showerheads rated at 9.5 l/min and kitchen and bathroom aerators rated at 8.35 l/min are inexpensive and have very high consumer acceptance. An additional benefit is that hot water tanks and equipment can be reduced in size and cost. Other measures can reduce DHW energy consumption. Complete insulation of storage tanks and hot water piping will reduce heating energy costs.

Heat losses from DHW storage tanks and piping can also be reduced by adding a set back feature to reduce hot water temperature to a minimum of approximately 46°C during the night time. Heat traps on inlet and outlet pipes also reduce heat losses.

Controls are available that match booster pump operation and water supply pressure to actual demand. Booster pump power consumption is thus reduced, while control of hot water pressure lowers hot water consumption. Significant energy savings can also be had from adding controls that shut down DHW recirculation pumps when demand is low (at night).

Hot water pre-heating can also be provided by condenser heat from chillers, heat recovery from grey water, and/or solar heating systems. Energy savings of 50% are achievable by combining heat recovery with water conservation strategies.

Major hot water savings are possible in buildings with common laundry facilities. Washing machine control cycles can be modified to allow cold rinsing only. Using water efficient horizontal axis machines reduces hot water use significantly and also has the advantage of reducing dryer energy requirements.

[1] Hewett et al, Heating Cost Allocation in Multi-family Buildings: Energy Savings and Implementation Standards, ASHRAE Transactions 95 (1), 1989.

RETROFIT OPPORTUNITIES

Energy consumption and cost can be reduced through a number of control system, suite metering, motor, auxiliary heater and domestic hot water retrofit opportunities. These can be carried out during renovation or equipment replacement or maintenance.

Control Systems

1 Installing energy management control systems that control peak electrical demand. Possible measures range from the installation of simple timeclocks that shut off non essential loads at times of peak demand to microprocessor control systems that control all sheddable loads in response to electrical demand.

2 Installing setback thermostats in individual suites to reduce night time heating energy consumption

3 Installing individual suite metering or energy cost allocation systems in individual suites

Motors

4 Replacing worn out electric motors with high efficiency electrically commutated or permanent split capacitor motors. Large electric fan and pump drive motors that have run long times are the most important motors to target for replacement.

Electric Heaters

5 Adding snow/ice and temperature controls to garage ramp heaters.

6 Adding thermostatic and timer controls to block heaters.

Domestic Hot Water

7 Installing flow restrictors on existing showerheads and faucets.

8 Replacing existing compression type taps with washerless type taps to reduce energy consumption associated with hot water leaks.

9 Adding insulation to existing DHW tanks and accessible distribution piping.

10 Adding heat traps to all DHW storage tank inlet and outlet piping.

11 Reducing hot water temperature to reduce heat losses from storage tanks and piping. The temperature in storage tanks should be reduced to the lowest level satisfactory to all tenants but not below approximately 49°C for safety reasons due to the growth of bacteria at lower temperatures.

12 Installing a mechanical timeclock on the hot water temperature controller of central DHW systems to reduce night time hot water temperature to a minimum of approximately 46°C.

13 Reducing DHW pressure at the top floor to reduce booster pump energy consumption. A minimum pressure of approximately 170 kPa (25 psi) during times of maximum demand is considered acceptable.

14 Installing timeclocks to shut down recirculation pumps during times of little or no use to reduce recirculation pump energy consumption and heat losses through poorly insulated piping. Recirculation pumps are typically shut off between 11:00 p.m. and 7:00 am.

15 Upgrading controls for multiple boilers to ensure that the first boiler is fully loaded before the next boiler fires, ensuring optimised system efficiencies.

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LIGHTING AND APPLIANCES

Related Topics

Space Heating and Air Conditioning

THE ISSUES

Electricity for lighting and appliances in an average high-rise building accounts for 15 to 20% of total energy consumption, of which 40% can be devoted to lighting.

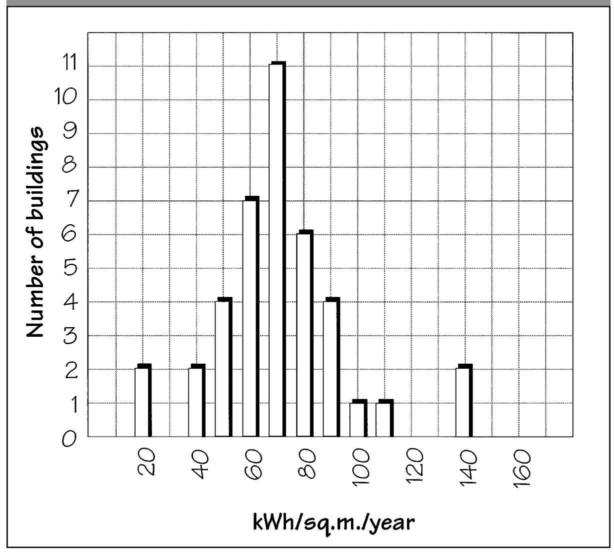
While lighting represents a large portion of electrical consumption costs, few designers and builders specify high efficiency lighting systems. As a consequence, higher operating costs are passed on to the building's occupants. Heat generated by lights (and appliances) is responsible for a significant portion of a building's cooling load requirements. In addition to lighting energy costs, the cooling equipment capital and operating costs are reflected in higher life cycle costs.

Energy efficiency of lighting must be balanced with architectural design, safety, and maintenance issues. Adequate lighting in exterior and underground spaces is an important safety issue. Lighting maintenance costs, are often not taken into account in the initial construction budget. The labour cost to replace a bulb is about twice the cost of the standard replacement bulb.

Lighting energy consumption can be reduced by as much as 75% with better design-improved distribution and layout, lamps and ballasts, and controls. Day lighting strategies that incorporate the use of higher performance windows can allow the designer to optimise window areas with a reduced space heating energy penalty. New day lighting techniques such as light pipes are also available to bring daylight into interior areas of buildings.

Switching from incandescent to compact fluorescent lamps in hallway fixtures can reduce lighting maintenance costs by 37%, and lighting energy costs by 78%, while improving lighting quality.

Electrical Energy Use Index for Apartment Buildings in Toronto (Based on 40 Buildings)



Similarly, replacing outdoor and parking garage incandescent lamps with high pressure lamps will reduce these annual lighting costs by 75%.

Advances in the design of appliances - stoves, refrigerators, washers and dryers - also demonstrate the potential for energy savings between 30% to 50% over conventional equipment. These performance levels can have a significant impact on operating costs over the life of the appliance.

This following discussion considers these issues as per:

- Lighting and
- Appliances

DESIGN CONSIDERATIONS

Lighting

Ordinary incandescent lighting converts only 15% of its electricity into usable light, with a life expectancy of between 750 and 1500 hrs. Fluorescent lighting is approximately four times as efficient as incandescent lighting, and bulbs typically last 10 times as long.

Standard fluorescent lighting systems with electronic ballasts are a suitable choice for many common area uses. Higher performance fluorescent lamps, called T8's or T5's, deliver higher light output and better light quality, with lower energy input. Compact fluorescent lamps can replace incandescent lamps using the same lamp fixtures. While costing more than incandescent bulbs, compact fluorescents have longer life and better energy performance, providing a rapid payback of their increased initial cost.

A number of advanced incandescent lights are also available. While less efficient than fluorescent lighting, they consume less energy than standard incandescent light bulbs and last longer. Halogen gas filled lamps can reduce energy consumption by 50% and last up to 250% as long as standard incandescent light bulbs.

Parabolic-aluminized reflector (PAR) bulbs last longer and can also reduce energy consumption. Standard PAR bulbs have longer life advantages, lasting up to 2000 hrs. "Energy Saving", "Halogen", and "IR" PAR bulbs have the same extended life expectancy but consume 20%, 40%, and 60% less energy respectively than standard incandescents.

High pressure sodium and metal halide lamps are efficient options for outdoor and garage lighting. High pressure sodium lighting is the most efficient high intensity discharge lighting available, using 75% to 80% less energy than standard lighting units and lasting for 18,000 to 24,000 hrs. Although they provide excellent contrast making them good for street and security lighting, their colour rendering is poor. Metal halide units are an efficient option when a whiter light with better colour rendering is required.

Electronic ballasts consume less energy than electromagnetic ballasts and also increase the efficiency of fluorescent lamps. Combined ballast and bulb efficiency increases are typically in the range of 20% to 35%. Dimmable electronic ballasts are available that can reduce energy use through dimming lights, without the losses in efficiency inherent in non-electronic ballasts.

Specular reflectors are another low cost option for increasing the light output from fixtures.

New emergency lighting systems include light emitting diode (LED) technologies, which typically reduce energy consumption to approximately 2 Watts from 15 to 25 Watts for incandescent lamps. They also have much longer life, reducing both energy and maintenance costs.

Proper lighting layout and design can significantly reduce the number of light fixtures required. Fewer fixtures save capital, operating, and maintenance costs.

Daylighting, combined with timers, motion sensors, and photocell controls for shutting off interior lights (when they are not required) can reduce energy use significantly. European experience with timer controls and motion sensor lighting systems demonstrates a more efficient use of lighting energy in parking areas, garages, corridors and stairwells, without sacrificing occupant security.

Appliances

Major home appliances may be provided by the builder. The energy efficiency of major appliances has improved significantly over the last decade, and minimum efficiency levels are regulated by the federal government. However, specification of higher performing models can result in savings of up to 50% in energy use.

Appliances are manufactured are rated according to Natural Resources Canada's EnerGuide energy rating system. EnerGuide appliance energy consumption ratings are published to assist in the selection of appliances.

Front loading horizontal axis washing machines that use between 35 to 45% less water and 60% less energy than top loading vertical axis washing machines. They typically cost about one third more than conventional units. They also reduce drying time and therefore lower energy consumption for dryers. Maintenance is reduced because they are simpler in design. They also increase accessibility for the elderly and people with handicaps.

RETROFIT OPPORTUNITIES

Lamps and ballasts can be replaced with more efficient models during routine bulb replacement as long as the ballasts are matched to the lamp type. During renovation or retrofit, lamps, ballasts and fixtures can be upgraded to provide more light of better quality using less energy. Appliances can also be upgraded one at a time with more efficient models during replacement at the end of their useful lives, or all at the same time as a retrofit measure. Some retrofit opportunities include:

Lighting

1 Reduce common area incandescent lighting levels. While common area lighting is provided for safety and security, in many buildings the number and wattage of incandescent bulbs can be reduced while maintaining acceptable light levels.

2 Replace indoor incandescent bulbs with compact fluorescent bulbs during routine bulb replacement. Incandescent screw-in lamps in corridors, lobbies, stairwells, laundry rooms, and other common areas can be replaced directly in many cases with screw in compact fluorescent bulbs. These lamps can also be used in fixtures in dwelling units.

3 Replace incandescent lighting with high efficiency fluorescent fixtures in common areas and in kitchens and bathrooms of rental suites. Common area lighting can be retrofitted at any time with minimal disturbance to tenants. Kitchen and bathroom lighting retrofits are best performed as suites are being renovated.

4 Replace incandescent lamps in exit signs with LED lamps.

5 Replace outdoor and parking garage incandescent lighting with high pressure sodium fixtures.

6 Install timeclocks and/or photocell control on outdoor lights to turn them off during the daylight hours.

Appliances

7 Modify washing machine control cycles so that only cold rinses are used on all cycles to reduce hot water energy consumption.

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ALTERNATIVE ENERGY SUPPLY SYSTEMS

Related Topics

Building Envelope
Space Heating and Air Conditioning
Mechanical Ventilation
Site Planning

THE ISSUES

While improving the end-use energy efficiency of high rise residential buildings is one method for reducing GHG emissions and other negative impacts of energy use, another is to use on site energy supply systems that are higher in efficiency or that make use of renewable energy sources that are low in GHG emissions and other negative environmental impacts. Renewable energy supply systems that use solar, wind, hydro, biomass and geothermal energy, as well as on-site co-generation and fuel cell technologies that make greater use of conventional fuel sources can deliver energy to the building with lower GHG emissions and other environmental impacts.

Strong advances have been made in developing high efficiency on-site energy generation and renewable energy technologies in the last two decades, including lower costs, higher efficiencies, improved quality and increased reliability, making their applications more attractive now than in the past.

The alternative systems considered here are:

- Co-generation
- Ground Source Heat Pumps
- Fuel Cells
- Solar Energy
- Daylighting
- Passive Cooling
- Wind Turbines

DESIGN CONSIDERATIONS

Co-generation

On-site co-generation is a highly efficient means of generating both heat and electric power at the same time from the same energy source. Micro co-generation systems appropriate to the individual high rise residential building level have excellent future prospects. In regions supplied by fossil fuel generated electricity, on-site co-generation systems can displace systems which generate electricity at 33% efficiency, with natural gas fired co-generation systems. These new co-generation systems generate both electricity and heat energy with combined efficiencies in the order of 80% to 90%, significantly reducing the GHG emissions associated with each unit of energy delivered.

Co-gen systems can provide electricity as well as heat for space and water heating in winter, and the waste heat can be used through absorption cooling to provide cooling in the summer. They can also be grid- connected to sell electricity back to the grid when extra capacity is available and where permitted by regulations.

These systems are more complex than equipment typically found in high rise residential buildings and require a turnkey operation or service contract approach.

Ground Source Heat Pumps

Ground source heat pump (GSHP) systems[1] utilise the heat from renewable solar energy stored in the ground (or water). GSHP systems are being installed in considerable numbers in a number of countries to provide space heating and/or cooling and hot water heating. They are an efficient means for providing space heating and cooling for buildings in Canada, and unlike air source heat pumps they remain efficient in cold climates.

GSHP units sold in Canada must exceed a COP of 3.0, resulting in 1/3 or less electricity consumed than with the use of electric resistance heating. Systems are designed as either closed-loop or open-loop systems. Closed-loop systems have closed piping systems installed in horizontal trenches, vertical bore holes, or lake bottoms, through which water or an antifreeze solution is circulated from an indoor heat pump. Open- loop systems use water from a lake or well that is pumped though the heat pump on a once-through basis. An optional de-superheater on the heat pump can provide water heating at much higher efficiencies than conventional hot water heating technology. Ground-source heat pumps are more expensive to install than gas, oil or electric heating units, but are more economical on a multi-unit basis, and typically demonstrate excellent life cycle costs when compared to conventional combination heating/cooling systems.

Fuel Cells

Fuel cells capable of providing all the electric needs of the average home are presently in the development stage, and may be on the verge of breakthrough as an economical alternative to traditional energy sources. Fuel cells convert the energy of fuel (hydrogen, natural gas, methanol, gasoline, etc) into electricity through an electrochemical process, without producing combustion emissions such as particulates, carbon monoxide, or nitrogen or sulphur oxides. Fuel cells running on hydrogen derived from renewable sources produce no CO_2 emissions. They can also run on other fuels, and generate less CO_2 than fossil fuel generated electricity due to higher efficiency levels. This advantage is further enhanced with recovery of excess heat for domestic hot water or space heating, in which case efficiencies of up to 70%-85% can be achieved.

Solar Energy

Off-the-shelf solar heating and electrical systems are readily available for pool heating, DHW heating, ventilation air heating, and photovoltaic applications.

Active Solar Pool Heaters

The most cost effective solar hot water heating systems on the market are solar pool heaters. Simple, inexpensive, unglazed black plastic solar collector systems are readily available that can provide all of the heating needs for residential multi-family outdoor swimming pools from spring until fall, eliminating both fossil fuel consumption and capital costs of conventional heating equipment. The systems are simple to install, and generally have 3- to 6-year simple payback periods.

Active Solar Domestic Hot Water (DHW) Heaters

Various active solar domestic hot water heating systems are available that vary in complexity, efficiency, and cost. Modern solar water heaters are now relatively easy to maintain, and can pay for themselves with energy savings over their lifetime. An efficient flat-plate solar hot water heater can collect approximately 2GJ/m^2 of collector area per year of energy in most of southern Canada. Other systems available include thermo-siphon systems that eliminate the need for pumps, which are common in Southern Europe. Evacuated tube collectors are more efficient, but also more expensive, with longer payback periods.

Active Solar Ventilation Air Heating

A technique available for reducing the energy required to heat ventilation air is to use solar energy to directly preheat the air drawn into the building. Commercially available systems of this type typically use a dark coloured perforated aluminium sheet mounted on a south-facing wall. As the sun heats the sheet, a fan draws solar heated air through the perforations. This preheating can significantly reduce the energy needed to bring fresh air up to room temperature. NRCan and Conserval Engineering are developing a new residential “Solarwall” that incorporates heat recovery ventilation.

Photovoltaics

Since 1980 the price of PV modules has dropped by approximately 80 percent, and there is currently a world-wide boom in PV sales, much of which is driven by government support for solar home systems in a number of countries. A number of technological advances and utility changes are making PV systems more attractive. One change is the availability of solar cells integrated into roofing shingles, tiles, and window glass. PV system costs are reduced by eliminating the cost of the roofing or window materials replaced by solar panels. Another change is the use of net metering, where the systems are connected to the grid, and utilities purchase the excess electricity generated, ideally at the same price that they sell electricity for. Battery storage systems and controls can be eliminated, substantially reducing costs.

Passive Solar Heating

Passive solar techniques collect thermal energy from direct sunlight, store the collected energy in the thermal mass of the building elements or other storage, and release it back into the interior of the building as required. Improved window technologies allow designers to increase solar gains to apartment buildings without the normally associated increase in heating load. The benefits of using passive solar techniques include simplicity, price, and the design elegance of fulfilling one's needs with materials at hand.

Daylighting

A related solar concept is daylighting design, which optimises the use of natural daylight. Use of light shelves and clerestory windows are two methods by which sunlight can be directed further into the interior of a room. They provide a more uniform level of illumination, while simultaneously reducing the building's cooling load due to heat gains from lighting. Full integration of natural and artificial lighting requires careful design and sophisticated lighting controls.

Passive Cooling

In cooler parts of Canada the need for air-conditioning in homes can be greatly reduced or even eliminated by using passive cooling designs. In hotter climates passive cooling techniques can reduce energy used for cooling during shoulder seasons. The terms passive cooling or natural cooling apply to various simple cooling techniques that enable the indoor temperature of buildings to be lowered through the use of natural energy sources. Usually the cold collecting and storage elements are an integral part of the building itself - such as the building envelope or structure, or the soil under the building. For removing heat from a building, natural cooling uses natural heat sinks such as ambient air, the upper atmosphere (radiation to the night air), water, or soil.

There are many different natural cooling techniques available to designers. The applicability of each technique varies greatly by climate, and therefore location, within the country. These techniques or systems can be classified according to the following broad categories:

- Comfort Ventilation - improving comfort when the indoor temperature is too warm by using natural ventilation to increase airflow of cooler outside air. The potential for cross-ventilation and stack ventilation strategies are often limited due to fire/smoke concerns in multi-unit buildings. However, proper design and placement of windows can increase airflow rates through windows on a single side of a suite, or increase cross-ventilation airflow through adjacent walls in corner suites.

- Nocturnal Ventilative Cooling - utilising a high thermal mass building which is cooled at night by circulating cool night air through the building or high thermal mass structures.

- Radiant Cooling - using the roof of a building, a heat storage mass on the roof, or lightweight radiators to cool the building at night. Surfaces will transfer heat to the sky through radiation at night.

- Evaporative Cooling - adding water to the air (such as with cooling towers) to reduce the air temperature in a process called adiabatic cooling. The cooled air is then circulated into the building, Another technique that uses evaporative cooling is to cool the roof of the building with a pond whose water evaporates to the outside air. These techniques are only effective in arid climates.

- Soil Cooling–circulating air or water through pipes in the soil where it is cooled.

For all passive cooling designs, solar and internal heat gains should be minimised through shading and proper daylighting design to optimise the use of natural daylight and reduce cooling loads. Other techniques that use vegetation and landscaping to aid natural cooling are found in the landscaping section of this document.

Wind Turbines

Wind power is rapidly expanding as a renewable energy source, particularly at the utility scale level. In the last decade costs for wind-generated electricity have dropped from 30¢ per kilowatt-hour to 7¢ per kilowatt-hour. Wind generated electricity may be practical on an individual building level under favourable site situations.

[1] Ground source heat pump systems are referred to under many names including geothermal, geo-exchange, earth-coupled, water-coupled, groundwater, ground-coupled, and water-source heat pump systems.

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- RETScreen Renewable Energy Project Analysis Software, CANMET Energy Diversification Research Laboratory (CEDRL) of Natural Resources Canada @ http://retscreen.gc.ca/

- Canadian Earth Energy Association @ http://www.earthenergy.org/

- The Canadian Wind Energy Association @ http://www.canwea.ca/

CASE STUDY

Dutch Apartment Building Has Largest Array of Solar Collector Panels in Europe

© Joost Brouwers

THE BRANDARIS BUILDING

The 14 storey Brandaris building, located 10 km north of Amsterdam, is a highrise with 384 apartments. The building was constructed in 1968 and recently renovated and retrofitted with a number of innovative energy saving features. The Brandaris now has flat-plate solar collector panels on its roof that transfer heat to augment its dometsic hot water (DHW) and space heating needs. It has a system for pre-heating its ventilation intake air which also saves on heating costs.

Renovation of the Brandaris was part of Thermie, a demonstration program for innovative energy technologies in the European Union. Results from the research of the International Energy Agency Task 20 'Solar Energy in Building Renovation' were used to determine the technical specifications of the collective solar system and the glazed balconies. The target was to design a solar system comparable with the best existing collective systems.

THE INNOVATION: SOLAR COLLECTORS

The combined heating system, which has been enhanced to meet the requirements for DHW, is fed by a solar boiler with 760 m^2 of collector area mounted on the flat roof. A heat exchanger is used to transfer the heat from collector panels to the boiler to heat the water used for DHW and space heating. It is the largest solar system on one building in Europe. The system provides at least 450 kWh (1.62 GJ) per m^2 collector surface per annum and at least 15% of the total energy demand for combined DHW and space heating. The system's solar combination boilers cost $250,000. The energy-saving retrofits cost an estimated $3000 per residential unit.

Further energy is saved with the enclosure of 42 balconies on the lower 3 floors of the building's eastside. They have been enclosed as atrium spaces for residences and also pre-heat mechanical ventilation air.

Another energy saving concept was used for lighting of the rooftop pavilion which looks out over the array of solar panels. Lights are powered with 30 m^2 photovoltaic cells. Anticipated savings from this lighting system are around 57% compared to conventional lighting.

CMHC SCHL

HOME TO CANADIANS

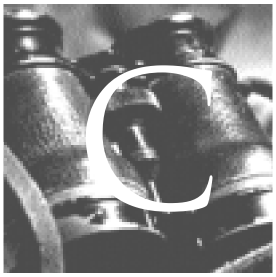
Canada

The solar collector area is 760 m^2, the largest on any building in Europe. The heat gathered via these flat-plate solar panels augments the domestic hot water and space heating system. The estimated cost for the flat-plate solar panels is $700,000.

The rooftop pavillion and PV panels in foreground, used to light the pavillion at night.

Project Info

Location:	Zaanstad, Netherlands
Architect:	Hans van Heeswijk Architect
Gross Floor Area:	W/E Consultants Sustainable Building
Number of Dwellings:	348 rental units
Completion Date:	1999
Further Information:	Woningstichting Patrimonium Postbus 23021 Phone +31 (0)75-650 47 72



CASE STUDY

Boston Highrise Retrofit Cuts Energy Costs by 15-percent

THE MARGOLIS

The Margolis is a 12-storey apartment building in Chelsea, Massachusetts, a suburb of Boston. The 150-unit building needed retrofit work as utility bills increased while occupant comfort decreased. From 1992 to 1996 it was the site of a joint study by the U.S. Department of Energy (DOE), the Department of Housing and Urban Development (HUD), the Boston Edison Company, and the Chelsea Housing Authority to analyze ventilation and airflow and the resulting energy costs. A series of ventilation and air-leakage measurements were made using tracer gases and blower doors. Following this, building airflow was modelled. Modelling showed that even apartments on the windward side of the building did not receive sufficient outside air (according to ASHRAE standard 62) during periods of low windspeed. High winds combined with cold winter temperatures magnified infiltration, conduction and interior air-flow problems throughout the building. Windward facing tenants responded by elevating baseboard settings over 26°C (80°F), while leeward tenants opened windows. The Margolis, as a result of the infiltration and ventilation problems, exhibited excessive demand for electric resistance heat. Post-retofit modeling showed large reductions in energy consumption, 90% of which was attributed to a comprehensive window retrofit that corrected air leakage problems.

THE INNOVATION: HIGH-EFFICIENCY WINDOWS

The Margolis retrofit involved windows as well as lighting and control retrofits in an attempt to decrease energy loads and improve tenant comfort. Double-pane low-E windows and a whole-building control system were installed to reduce and control heating load problems. These retrofits reduced severe infiltration and drafting loads, regulated 'out-of-control' set point temperatures and diminished inefficient interior and exterior lighting problems in the all-electric building.

The replacement windows were Peerless 4320 double hung units. The frames were heavy commercial, thermally broken aluminum with an HC-45 rating. The low-E coating was a "hard coat" directly applied to the glass, and the assemblies were Argon-filled. The existing pre-retrofit glass had a conductance value of 5.0 W/(m^2 ok) and an RSI-value of 0.2. The new glass had a conductance value of 3.48 W/(m^2 ok) and an RSI value of 0.29. The new apartment glass also had a U-value of 0.33.

Lighting retrofits also captured savings by replacing circa 1972 lighting with more efficient products.

Pre-retrofit annual consumption for the building was over 2,100 MWh, with a peak demand of 594 kW. Annual consumption was reduced by 325 MWh (15%) with the retrofit. Peak demand was reduced by 100 kW (17%).

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Infiltration Location	Pre-Retrofit	Post-Retrofit
Apartments	0.8 ACH (0.11 cfm/ft2)	0.68 ACH
Corridors	0.2 ACH (0.026 cfm/ft2)	0.17 ACH
Stairwells	0.7 - 1.89 ACH (0.11-1.99 cfm/ft ^{2})	0.59 - 1.55 (0.09-1.22 cfm/ft ^{2})
Elevator Shafts	0.7 - 1.89 ACH (0.11-0.29 cfm/ft ^{2})	0.55 - 1.6 ACH (0.09-0.25 cfm/ft ^{2})

Annual energy cost savings from the retrofits totaled $28,000 (over 90% was attributable to the window retrofit). The cost of retrofit was $305,000 or $2905 per unit.

Project Info

Location: Boston, Massachusetts

Host Organization: Chelsea Housing Authority

Number of Dwellings: 150 units

Completion Date: 1996

Further Information: Chelsea Housing Authority
54 Locke St.
Chelsea, MA 02150
Tel: (617) 884 5617
and
"DOE-HUD Initiative - Impact evaluation of the energy retrofits installed in the Margolis High-Rise Apartment Building, Chelsea Housing Authority." by M.M. Abraham, H.A. McLain, and J.M. MacDonald. @ http://www.ornl.gov/~webworks/tlp/tlp_web.htm
Report Number: ORNL/CON-413