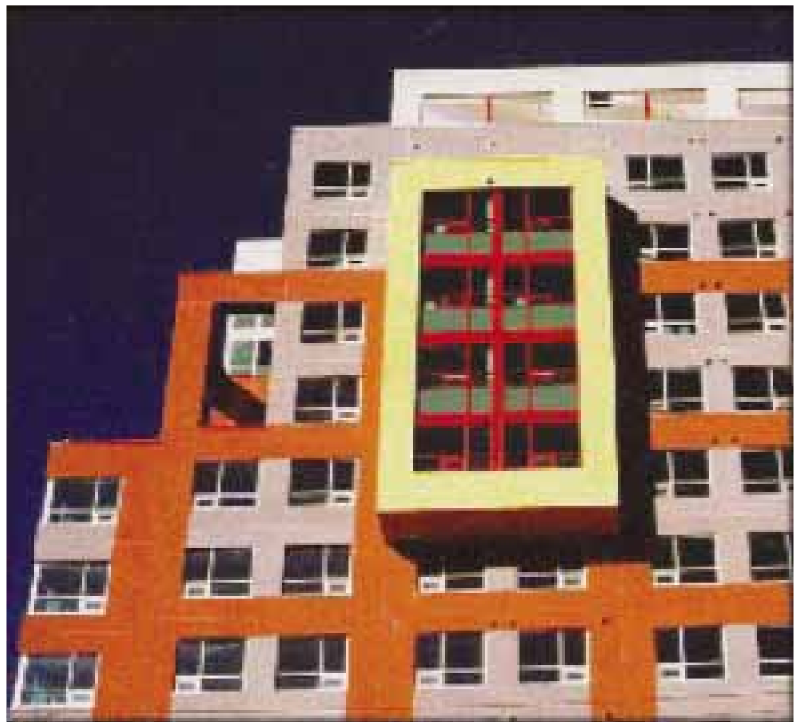
HEALTHY HIGH-RISE

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



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Healthy High-Rise

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

Canada Mortgage and Housing Corporation

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An update of the "IDEAS Challenge Better Buildings - A Guide to Innovation in the Design and Construction of High-Rise Residential Buildings"

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Cette publication est aussi disponible en français sous le titre: Guide de conception des tours d'habitation saines, 62806

The information contained in this publication represents current research results available to CMHC, and has been reviewed by a wide spectrum of experts in the housing industry. Readers are advised to evaluate the information, materials and techniques cautiously for themselves and to consult appropriate professional resources to determine whether information, materials and techniques are suitable in their case. The drawings and text are intended as general practice guides only. Project and site-specific factors of climate, cost, aesthetics, and so on must be taken into consideration. Any photographs in this book are for illustration purposes only and may not necessarily represent currently accepted standards

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THE NEED FOR CHANGE

High-rise residential buildings play an important role in expanding Canadians' housing choices. The buildings provide housing choices ranging from affordable housing for low income renters through to luxury units in some of Canada's most prestigious locations. It is estimated that 20% of Canadians live in multi-unit residential buildings.

While the benefits of these housing choices are generally considerable - proximity to services, public transportation, efficient use of land and infrastructure - the quality of the housing units has not reflected recent technological advances.

A list of common inadequacies include:

- water penetration and air leakage through the building envelope resulting in structural and other damage, high energy cost and occupant discomfort,
- inadequate thermal envelope performance and thermal bridging resulting in occupant discomfort and high energy bills,
- HVAC systems influenced by strong building stack effects and wind pressures which result in poor comfort levels and poor indoor air quality,
- insensitive use of land which impacts on stormwater flow,
- high domestic water consumption,
- occupant dissatisfaction relating to noise levels,
- a lack of accessibility to people with disabilities.

These problems are not solely those of the building occupants. Increasingly across the country, the cost of remedial repairs and replacement of deteriorating components of the building are being legally passed back to the developer.

In all too many instances, repair costs for new buildings are being assumed by Warranty Programs, thus depleting their reserves. In Ontario alone, warranty claim payouts for high-rise buildings are approaching $20 million annually.

Researchers, architects and engineers in the field agree that better performing buildings can be constructed. They acknowledge that improving performance will require changes in the design and construction process, requiring more comprehensive and improved building detailing, enhanced quality control and building commissioning processes, improved building operation and maintenance procedures, and understanding the building construction and operation as a whole.

Over the last several years, building scientists, researchers and practitioners with considerable expertise have invested substantial resources and energy in identifying the causes of typical problems in high-rise residential buildings, and in developing improved design and construction procedures that could significantly reduce defects and improve building performance.

An improved understanding of all facets of high-rise design and construction is being developed relating to virtually every aspect of high-rise buildings. Upgraded parking garages, enhanced envelope durability through rainscreen and air barrier design, improvements to the building thermal envelope, better heating, cooling and mechanical ventilation systems, measures to improve the accessibility and functioning of buildings, and measures for improving the environmental performance of these buildings and the inter relationship between these systems have all been the subject of recent investigation by government and housing agencies.

Canada's building design and research community has historically been at the forefront of innovation in the Canadian construction industry, maintaining our reputation for providing some of the best housing in the world. Until recently, much of the innovation was concentrated on the low-rise housing stock where we are acknowledged as world leaders in the provision of energy efficient, environmentally-responsive housing. It remains for the high-rise design and building industry to assume a similar leadership role.

This document is designed to reflect the innovation that can lead to the design and construction of better performing buildings. It provides:

- an overview of many of the problems affecting high-rise buildings which result from conventional practices,
- insight into an improved understanding of the building science principles, and
- design considerations for improving building performance in a variety of areas.

This document is intended to present alternative ways of thinking about design principles for high-rise buildings, to provide some different approaches to design, construction, commissioning and operations and maintenance. In many cases, it presents the need for a more holistic and integrated approach to the design and construction of a high-rise residential building. This type of integration is displayed in the "Related Topics" table at the beginning of each sub-section. Issues related to retrofit opportunities and regional differences are also discussed when they apply.

Opportunities are also discussed for improving the integration of high-rise residential buildings with the surrounding urban infrastructure, including on-site systems for energy and water supply, transportation and waste management.

Finally, each section includes "Sources of Information" to recent research and development studies. The industry is encouraged to follow-up on these reports that reflect some of the best and most current information on high-rise buildings.

As innovative practices are adopted, implemented and monitored in high-rise buildings, our knowledge and understanding will be greatly enhanced. Readers are encouraged to share their experiences with CMHC.

BUILDING FAILURES

THE PROCESS

To a large degree, high-rise buildings across Canada should be capable of better performance. Opportunities exist to correct specific building defects and deficiencies. But, as one analyses the problems, the causes often appear in the design and construction processes.

Those involved in the various aspects of a high-rise project often perform their own role in isolation from others. When problems arise, there is invariably “finger pointing” at the role of others in the process - architects suggesting that workmanship is poor, contractors stating that details were not buildable, engineers suggesting the developer needs to provide more funds for site inspections, and so on. The benefits of a team approach are seldom witnessed.

Only through a review and rethinking of the process will many of the following problems be resolved. Through the use of an integrated design process, where all disciplines collaborate to develop the building as a system of mutually beneficial components, improvements in durability, efficiency, comfort and aesthetics can be achieved without cost surcharges.

Design Deficiencies

Researchers have been able to draw a direct correlation between the limitations of project designs and problems in high-rise buildings. They single out inadequate details and incorrect details (reflecting a poor understanding of building sciences) as common problems. And the rationale for specific details is usually not effectively communicated to the field.

Construction Deficiencies

Even where plans and specifications are excellent, problems can arise. Specified materials are frequently substituted for those which are not compatible in their place of application. Manufacturers’ installation requirements can be short-circuited by trades. Training of sub-contractors is ad hoc and project quality control measures are seldom sufficient. From the conceptual stage, a more active role of an integrated project team in ensuring that construction meets the project requirements is essential to improving building performance. However, this can only be achieved if the owner/developer commits to the process in advance of this step.

Commissioning and Testing

Non-existent or inadequate commissioning and testing protocols fail to detect construction defects, resulting in increased costs for building owners and operators.

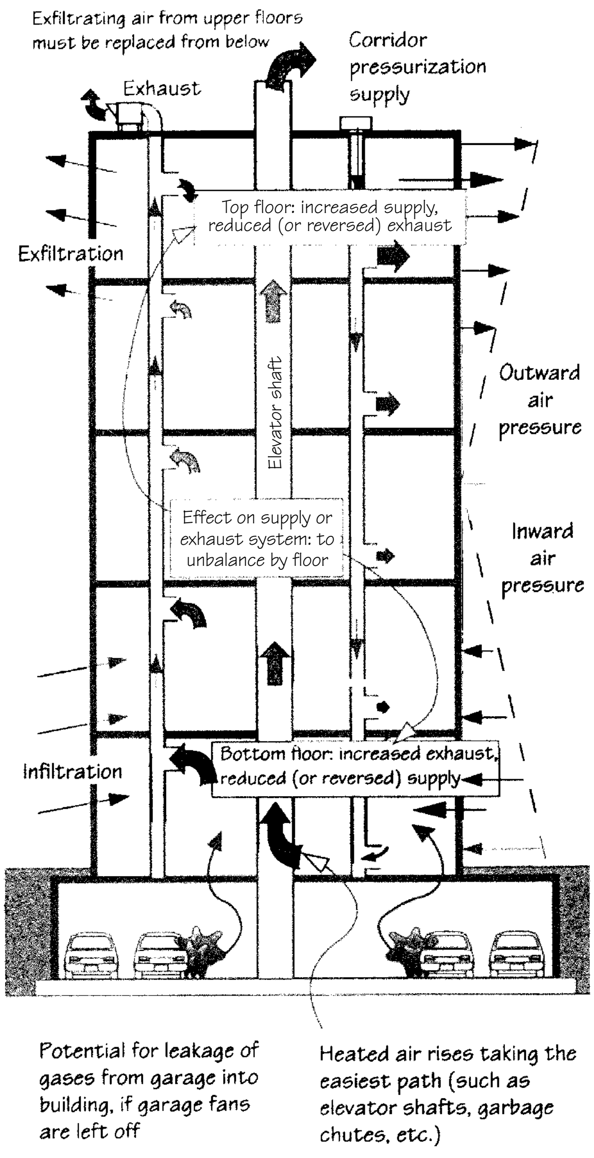
All too often, problems are identified at a late stage in the construction process, or after building is occupied requiring costly remedial work. Mock-up testing of typical sample assemblies is an essential tool in ensuring that the project will operate as intended. More often than not, the cost of testing pays for itself within the construction period as well as saving costs thereafter.

Operations and Maintenance

Frequently, a building is “turned over” without any formal communication about the operating and maintenance requirements. The project team must assume responsibility for communicating their design assumptions, operational expectations, and maintenance requirements to the property manager. Operations manuals must be prepared, and staff must be trained to perform regular maintenance to minimize more costly remedial and repair work and to ensure efficient functioning of all building systems. Documentation must also be prepared for tenants/owners as well as walk-through demonstrations.

Most of the problems that occur in high-rise residential buildings are the result of interplay between the movement of air, moisture and heat. An improved understanding by designers of the forces acting in a high-rise building is essential to better performance.

Air Movement in Buildings in Winter



THE PRINCIPLES

Air Movement

High-rise buildings are subjected to a variety of pressures affecting air movement: wind pressures, the stack effect, and mechanically induced pressures.

Winds can exert significant pressures - positive pressures on the windward side and negative pressures on the lee side of the building. These pressures will force air into the building and draw air out of the building in other areas through any leaks or cracks in the building envelope. Gust loads on high-rise buildings can be as high as 2500 Pa, exerting significant structural forces on the air barrier system.

In winter, air movement is also affected by the stack effect, which results in cooler air entering the lower levels of the building, and rising within the buildings as it is warmed and becomes more buoyant. The higher the building, and the greater the temperature difference between the inside and outside, the greater the stack pressures. These pressures can be as high as 50 to 150 PA in 10-storey buildings.

The operation of exhaust fans and the exhausting of combustion gases can impose negative pressure in buildings, and draw outside air into the building through unintentional leaks in the building envelope when supply air is inadequate.

The combined effect of these pressures will vary on a daily, hourly and even instantaneous basis. Cold outside air will be drawn into the building through the envelope, while at the same time warm moist air will be driven from the inside through the exterior walls and roof in other areas.

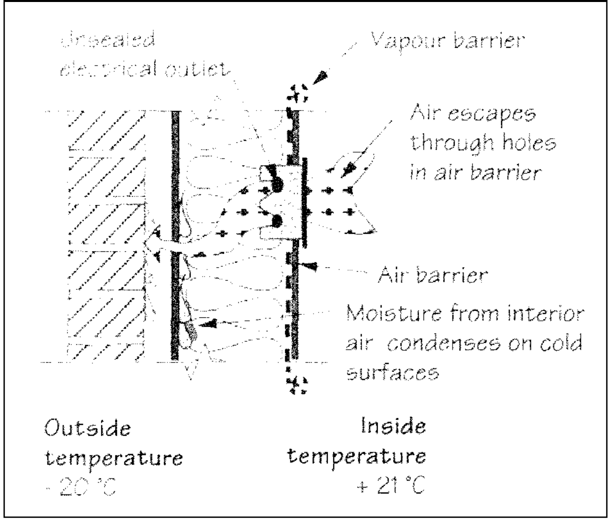
The effect of air leakage on building performance is significant. On the other hand, the infiltration of cold exterior air causes occupant discomfort and fuels the stack effect, and on the other the exfiltrating air carries moisture causing detoriation of the building envelope.

Unless understood in the design process, airflow associated with the stack effect can also result in backdrafting of combustion appliances as well as uncontrolled smoke movement during fires. Stack pressures can also affect occupant comfort. Lower levels of the building are often underheated, while upper levels are overheated.

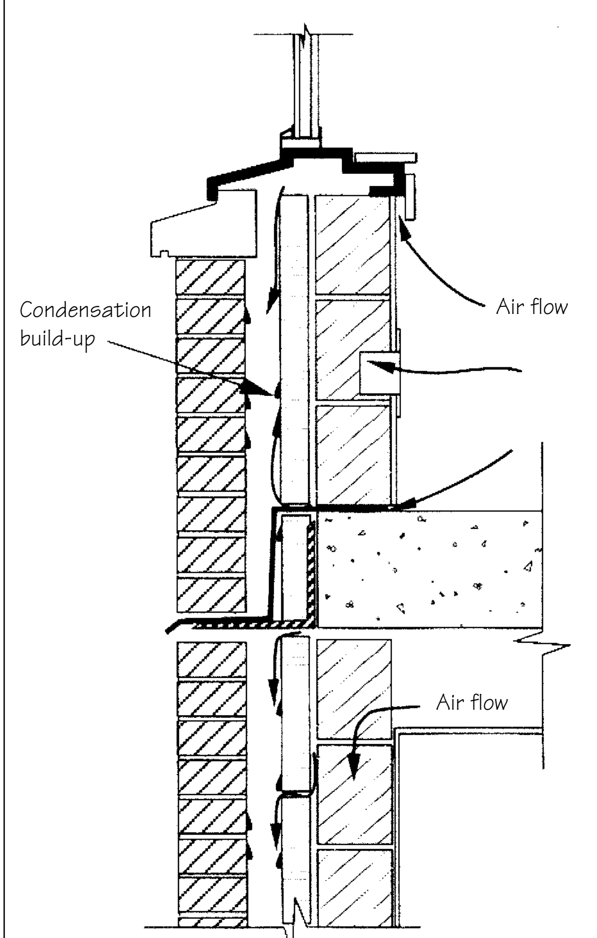
Airtightness

For air to move through the envelope there must be a pressure difference and a leakage path. The negative effects associated with wind, stack and exhaust pressures are a direct function of the

Wall with Discontinuous Air Barrier



Typical Problems



Condensation from moist air exfiltrating
if effective barrier not in place.

airtightness of the building envelope. If the building were completely airtight, there would be no airflow. Pragmatically this is not possible. But significantly increasing the airtightness of a building is achievable - and is the cornerstone of enhancing envelope durability, occupant comfort, and HVAC system performance.

Tightening the building envelope will effectively counter the movement of air caused by the stack effect in buildings. By reducing leakage paths, uncontrolled air movement will be greatly reduced, allowing for improved comfort.

Airtightness prevents moisture migration into and out of the building envelope. Typically in winter, warm moist air will exfiltrate through the upper storeys of a building. As the moisture carried in the air comes into contact with the colder surfaces of the assembly, it will condense. This moisture is a primary cause of structural deterioration of components of envelopes and results in corroding fasteners, deteriorating cladding and wetting of thermal insulations. Envelope airtightness is also essential to the proper functioning of pressure equalized rainscreen walls.

Improving building airtightness will serve valuable functions. To the building occupant, it will result in improved comfort, reduced drafts, improved health, more effective HVAC systems and reduced energy costs. To the building owner, it will allow for the integration of smaller, less expensive, more appropriately sized mechanical equipment, reduced operating costs, and result in enhanced building durability and longevity.

Moisture Movement

High-rise buildings are subjected to the effects of water and moisture in a variety of manners. Outside moisture can penetrate the shell of the building and leak into the building interior. This moisture can result in deterioration of connectors and the eventual failure of building cladding systems as the moisture goes through freeze/thaw cycles. Common problems with rain or melting snow leakage occurs through roof membranes, around windows and behind flashings on walls, projections from building envelope and through cracks in foundation walls and parking garage roofs.

A more invisible force is the movement of water vapour through the building envelope by exfiltration (and to a lesser extent by vapour diffusion). This vapour will condense within the envelope as it comes into contact with cooler surfaces. This moisture migration commonly results in efflorescence, spalling, delamination of facing materials and other structural damage. The movement of water vapour can also cause mold and rot within walls which is a health, aesthetic, and eventually a structural concern.

Key control mechanisms to ensure that water and moisture damage in high-rise buildings is minimized will include:

- improved detailing and construction of walls and roof membranes (particularly around penetrations and at parapets),
- shedding water away from building envelope,
- the use of pressure equalized rainscreen wall systems,
- improved air leakage control,
- better detailing and construction and water sealing of building foundation walls and garage and terrace roofs,
- particular attention to detailing of joints between materials.

Sources of Information

- *Construction Problems in Multi-Family Residential Buildings: A Documentation and Evaluation*, CMHC, 1991.

- *Field Investigation Survey Summary Report of Airtightness, Air Movement and Indoor Air Quality in High-Rise Apartment Buildings in Five Canadian Regions*, CMHC, 1993.

- *Controlling Stack Pressure in High-Rise Buildings by Compartmenting the Building*, CMHC, 1996.

IN THIS SECTION

Air Barriers
- continuity
- windows
- structural support
- impermeability to air flow
- durability
- quality assurance

Wetting of Building Envelopes

Pressure-Equalized Rainscreen
- air barrier system
- sealed compartments
- venting
- assymetrical venting
- quality control

Exterior Insulation and Finish Systems (EIFS)
- rain penetration at joints
- interstital condensation
- cracking of the lamina

Parking Garages
- positive drainage
- reduced cracking
- elevated joints
- surface protection

Low Slope Roofing Systems
- seams
- membrane moisture
- ballast
- standing water
- green roofs

Regional Differences

The building envelope consists of the materials, assemblies and components that separate the interior of a building from the exterior. It includes such elements as walls, windows and doors, roofs, floors and foundations. The function of these elements is to enclose space in such a way that appropriate interior environmental conditions (temperature, humidity, air movement, light) can be maintained.

Premature failure of building envelopes occurs in many buildings throughout the country. These failures result in the deterioration of the exterior facade of buildings, damage to building interiors, dangerous long-and-short-term structural situations, and potential adverse health effects to occupants as a result of exposure to molds.

The knowledge and technology required to design and construct building envelopes that are free of problems is now available. A more durable envelope, requiring less maintenance, is the result of improved understanding of applied building sciences, improved detailing on construction drawings, and greater attention to detail in the construction and commissioning of the building envelope.

By understanding the movement of moisture through the building envelope, whether the moisture is from the outside or inside, the primary cause of premature deterioration can be controlled. Enhanced envelope performance can be achieved through greater envelope airtightness, improved water management capabilities, and the application of pressure equalized rainscreen systems and proper water shedding details.

The following section provides an overview of improved approaches to air barrier systems, rainscreen design and commissioning requirements, water-shedding wall construction, and improved practices relating to the design and construction of parking garages and roof systems. In each case, changes to the design, construction and commissioning of the building envelope are required to ensure improved durability.

AIR BARRIERS

Related Topics

Pressure Equalized Rainscreen
Building Envelope
Mechanical Ventilation
Occupant Comfort - Noise

THE ISSUES

Despite the importance of the air barrier to overall building performance, air barrier technologies are just beginning to be understood. Consideration of the air barrier system is often not fully integrated into the design process.

An effective air barrier (or more specifically an effective air barrier system, made up of all the materials, components and joints functioning to prevent the migration of air) is an essential component of a well performing building envelope in all climatic regions. The effectiveness of rainscreen designs, improved insulation levels, ventilation and interior comfort are each dependent on air barrier performance. The air barrier system will restrict the movement of air through the envelope, thereby reducing the primary transfer mechanism of moisture. Control of air movement will also improve comfort, envelope durability, and energy efficiency.

Effective air barrier systems require:

- thorough detailing and specification of materials and components,
- careful quality control and testing during construction,
- a comprehensive quality assurance process including commissioning (performance verification) of installed systems.

The National Building Code requires that buildings be designed to provide an effective barrier to the infiltration and exfiltration of air. The Code prescribes airtightness requirements for individual materials used in an air barrier system. In addition there are recommendations for the overall air barrier system leakage rates.

Recent studies undertaken for CMHC of the air leakage characteristics of high-rise residential buildings have indicated air leakage rates for the building envelope ranging from 1.3 to 12.8 L/(s x m^2) at 75 Pascal pressure difference. These rates are considerably in excess of the NBC recommended rates of 0.05 to 0.20 L/(s x m^2). It is clear that high-rise building envelopes are not performing as needed with respect to air leakage.

Poor air barrier performance is the primary factor in:

- structural defects and damage to exterior cladding & interior finishes resulting from the exfiltration of warm, moist air into the building envelope,
- occupant discomfort and freezing pipes associated with the infiltration of cold outside air through the building envelope,
- air flows (stack effect) in buildings which prevent the efficient operation of ventilation systems and interzonal air movement,
- high building energy costs associated with the heating of outside air,
- rain penetration through the building resulting in deterioration of the exterior assembly damage to interior finishes and,
- growth of mold in and on exterior walls and adjacent surfaces.

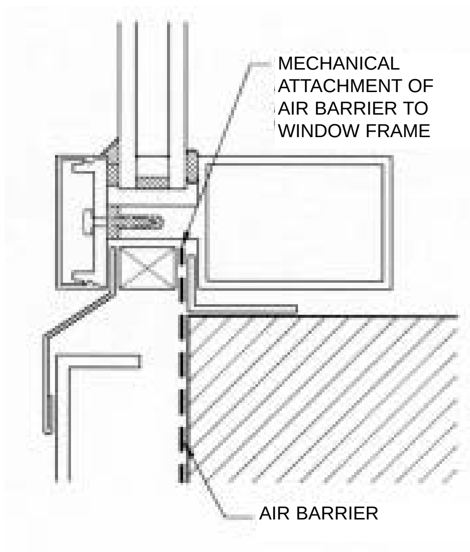
Poor air barrier performance is commonly a function of incomplete understanding of air barrier concept by designers and constructors resulting in:

- inadequate or missing details on building plans,
- poor selection, installation and quality control of materials included in the air barrier system,
- deterioration of air barrier systems.

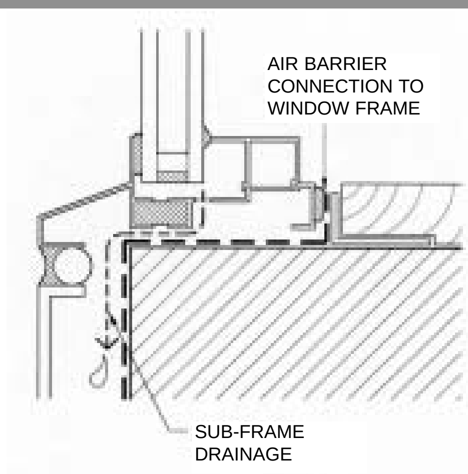
There are a range of elements that need to be considered when discussing an effective air barrier system. They are:

- Continuity
- Structural Support
- Impermeability to Air Flow
- Durability
- Quality Assurance & Air Barrier Commissioning

Mechanical Connection of Air Barrier at Curtain Wall Window



Connection of Air Barrier to Allow for Drainage of Water Below Window Frame



DESIGN CONSIDERATIONS

Continuity

The air barrier is made up of a variety of materials, components and joints. The air barrier should be viewed as a system typically comprised of sheet or membrane materials (for example, on walls and roof, windows, metal curtain wall panels), and sealant and gasketing materials intended to function as joints providing an airtight seal.

Not only must all components of the air barrier system be correctly selected, designed, and installed with airtight and durable connections, but the air barrier system must also be effectively sealed to all penetrations in the envelope including through windows, ducts, vents, electrical conduits and fixtures.

Detailing of joints and connections must reflect an understanding of material compatibility, ensuring adequate strength, adhesion and elasticity of attachments, to accommodate differential component movement and the need for structural support. All elements of the air barrier must be designed to perform over the expected life span of the building or be readily accessible to allow repair or replacement without damage to other envelope components.

Windows

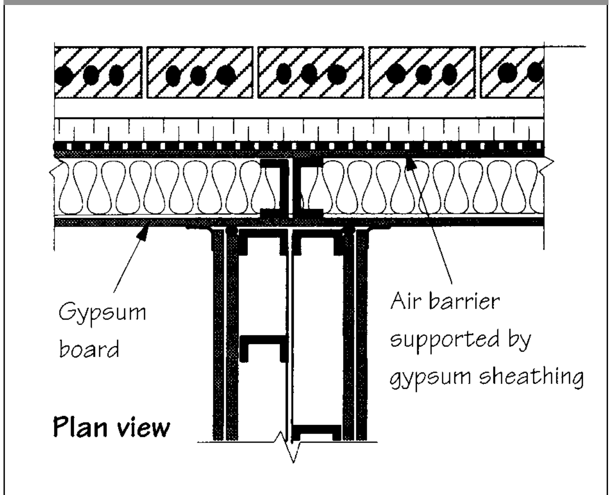
Windows form a key component in building envelope systems and must satisfy air barrier requirements. Both the window unit itself, and the connection to adjoining assemblies must be designed to perform as part of the building air barrier system.

CSA A440-98 provides performance requirements for factory built windows including air tightness requirements. The air tightness rating (the A-rating) provides a maximum air leakage rate expressed in $(m^3/h)m^{-1}$. The User Selection Guide, A440.1-98, is a companion document to the standard, and provides information to assist designers in selecting the appropriate rating for windows in various applications. CSA A440.2 deals with the energy performance of windows and other fenestration systems.

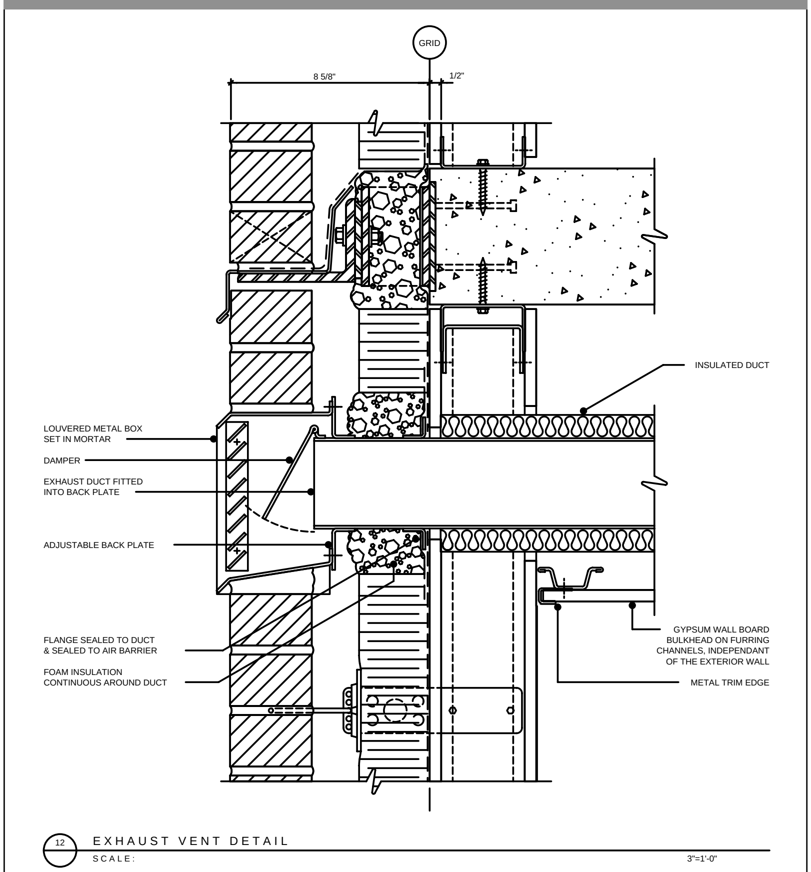
CSA A440.4 covers the installation of windows. This standard provides minimum requirements to help ensure that windows are installed in an effective manner, such that the performance, as established by A440 or A440.2 testing, is not compromised.

Continuity of air barriers at window-to-wall interfaces may be achieved through a number of means, including mechanical connection of the

VB and Continuous AB Past Partitions



Exhaust Vent Detail



wall air barrier to the window, sealants, self-adhesive membranes or urethane foams.

The most appropriate method will depend on the type of window used and on other performance characteristics of the window. With some window types, provision for drainage of water from the window frame is required. In this case the air barrier connection must be made in a manner that will not impede movement of water to the exterior or to a drainage cavity in the wall assembly.

Structural Support

The design must ensure that loads on the air barrier materials, and joints between materials, are transferred to the building structure. Unsupported air barrier materials, such as polyethylene or polyolefin housewraps, are incapable of bearing the continuous and peak loads imposed by the stack effect, mechanical ventilation and wind pressures in high-rise buildings. The air barrier must also be strong enough to withstand the effects of thermal expansion and contraction, especially at joints in the air barrier system. The design should also take into account the creep characteristics of the materials in the air barrier assembly and the need to mechanically/structurally support all joints.

Impermeability to Air Flow

Impermeability of the air barrier must be addressed in terms of:

- impermeability of materials and components that make up the air barrier system,
- the impermeability of the overall system.

The National Building Code specifies that individual sheet and panel materials that form part of the air barrier system should have an air leakage rate no greater than 0.02 L/(s x m^2) measured at a pressure difference of 75Pa. In order to meet this requirement designers need to familiarize themselves with the air leakage characteristics of different materials which may be used to construct the air barrier system.

In addition the Code recommends that the complete air barrier system should be designed to provide maximum allowable air leakage rate, depending on exterior and interior temperature and humidity conditions.

Warm side RH at 21Lc	L/(s x m^2) at 75Pa
<27%	0.15
27% to 55%	0.10
>55%	0.05

NOTE: CCMC's permissible air leakage rates differ from those proposed in the NBC Appendix A-5.4.1.2. The rates proposed in the Code are not based on the drying potential of the wall assembly, CCMC's requirements are. There are four permissible air leakage rates that were established. They vary between 0.05 to 0.2 L/s x m^2 at 75 Pa. CCMC's permissible air leakage rates were developed taking into account that the building will be operated at relative humidity around 35% for standard ambient temperature conditions.

Durability

The performance of the air barrier system is a key factor in ensuring long-term building durability.

The CSA S478-95 *Guideline on Durability in Buildings* provides suggestions with respect to the design service life (life span) of both buildings, and individual systems, components and assemblies. Residential buildings are classified as long life buildings with recommended design service lives of 50 to 99 years.

The standard recognises that individual components and assemblies (for example air barrier materials or cladding) may have design service lives that are shorter than that of the overall building. The designer may choose to use an air barrier material which is not intended to last the full service life of the building. In this case, however, it is important that the air barrier be located so that inspection and repair or replacement can be carried out without damage to building components with longer design service lives (see table "Air Permeability of Selected Building Materials ..." in Design Considerations for an Air Barrier System, CMHC).

Quality Assurance

To improve the construction industry's ability to predict the performance and durability of the air barrier system, better information must be provided to all involved in building delivery, from the owner through to the eventual user. Effective commissioning of the air barrier system should be part of an overall project quality assurance process. Quality assurance begins during the design process and includes the following stages:

1 Project Brief / Performance Specification
2 System Design
3 Testing / Confirmation of Performance
4 Field Review / Inspection
5 Documentation

1 Project Brief includes:

- the design conditions
- the performance objectives for the air barrier assembly, component parts and joints
- durability and maintenance expectations,
- procedures to be followed in commissioning the air barrier system.

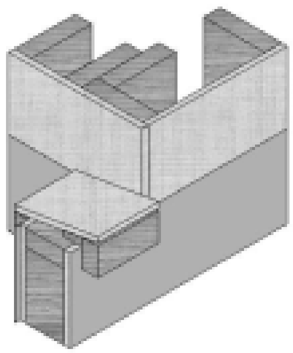
2 System Design includes:

- specification of air barrier system and key component air leakage restrictions,
- specification of materials with tested air permeability ratings,
- details showing how design loads on the air barrier are transferred to the structure,
- details (including three-dimensional details) for continuity and connections.

3 Testing / Confirmation of Performance

The contract documents should include provision for construction and testing of mock-ups. Mock-ups are full size construction of important or difficult assemblies. They can be constructed separately from the actual building or can be incorporated into the final construction. In addition to testing of mock-ups, it is useful to carry out testing of selected typical assemblies and details. Test locations should be randomly selected, and the test protocol should include provisions for re-testing in the event of failure to meet specified levels of air tightness.

SADDLE 1



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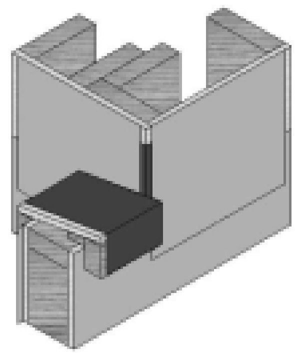

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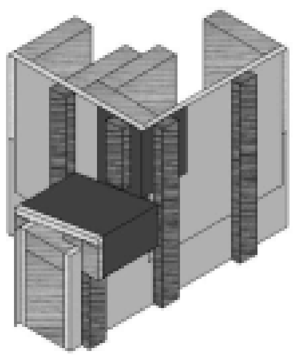

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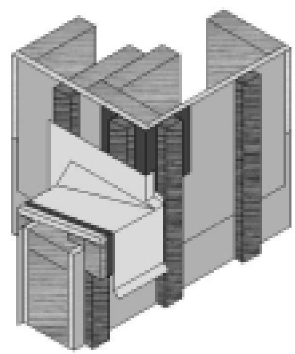
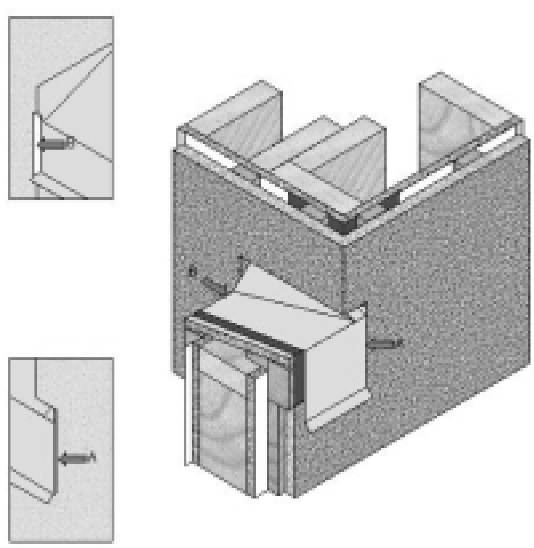
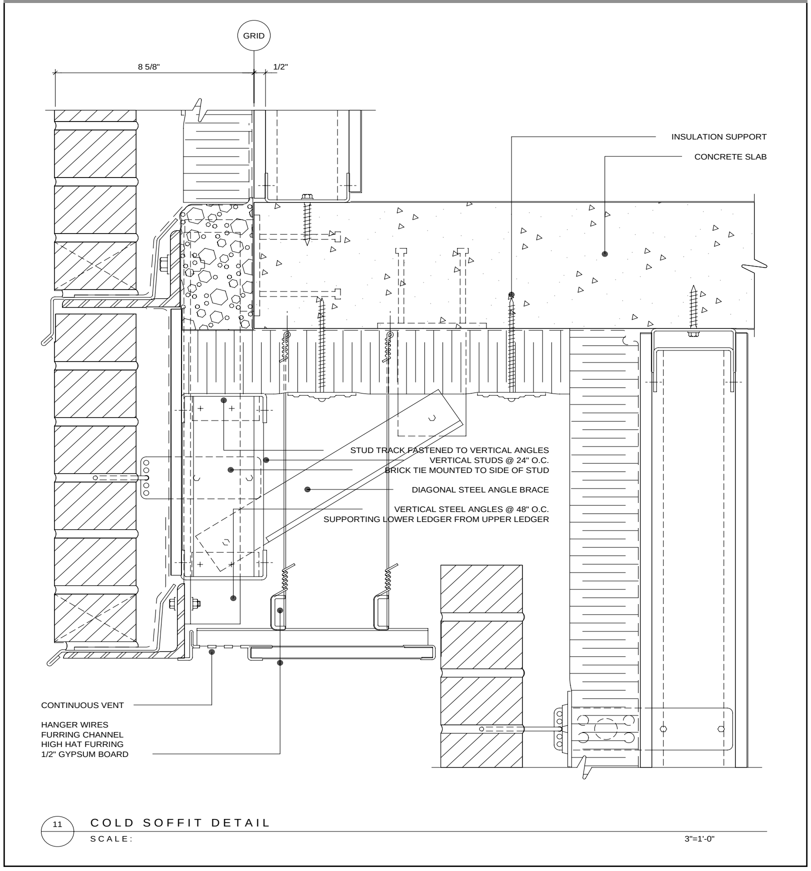


SADDLE 5

A '4-D' detail taken from the CMHC Best Practice Guide: Wood-frame Envelopes in the Coastal Climate of British Columbia, showing the step-by-step assembly of a Saddle Joint. This type of detail (showing assembly over time) can be incorporated into 'System Design' specifications (see Quality Assurance in Air Barriers).



Low Parapet Detail



Test procedure ASTM E783 is used to perform progressive testing of individual assemblies and components. In addition overall performance of the total air barrier system can be confirmed using CAN/CGSB B2-149.15-M96.

4 Field Review / Inspection

Field reviews should verify that assemblies and details are constructed in conformance with the design documentation and that the specified materials are used. It is also necessary to confirm that modifications or revisions arising from construction and testing of mock-ups are incorporated. Field reviews are also required to address atypical details, or changes required as a result of unforeseen circumstances arising during construction. It is important that field review personnel be familiar with air barrier design concepts as well as with the requirements in the project brief.

5 Documentation

Upon completion of construction, a building operations manual should be provided to the owner. The air barrier section of the manual should include:

- the original project brief,
- a description of building operating conditions (RH levels, expected pressure differentials),
- design documents (including a record of changes or modifications made during construction),
- a description of testing and test results verifying compliance with project brief requirements,
- monitoring and inspection procedures and maintenance and repair requirements.

RETROFIT OPPORTUNITIES

Retrofit of an effective air barrier should be considered in building envelope renovation projects, or where cladding is to be replaced. In most cases air barrier retrofit will be carried out in the context of a larger cladding or envelope renovation project.

The effects of adding or changing materials on the overall wall assembly need to be carefully considered. Self-adhesive membranes, applied to the exterior of sheathing board, are often used in retrofit applications to provide an air barrier. However they will also act as a barrier to the diffusion of interior moisture. If existing insulation on the interior side of the sheathing remains in place there is the potential for interstitial condensation. In this case an exterior insulation wall assembly should be considered. It will be necessary to remove sheathing to allow removal of interior insulation and a polyethylene vapour barrier if provided. In many high-rise building envelope retrofit projects existing cladding will be replaced with rainscreen cladding. The use of polyolefin house wrap type air barriers is not appropriate in this application.

Sources of Information

- *The Development of Test Procedures and Methods to Evaluate Air Barrier Membranes for Masonry Walls*, Ortech International for CMHC, 1990.
- *National Building Code of Canada 1995*, National Research Council Canada, 1995.
- *An Air Barrier for the Building Envelope*, Insitute for Research in Construction/National Research Council Canada, 1986.
- *Commissioning and Monitoring the Building Envelope for Air Leakage*, Morrison Hershfield for CMHC, 1994.
- *Testing of Air Barrier Construction Details*, CMHC, 1991 and 1993.
- *EMPTIED Version 3*, a computer program to aid in wall design by estimating potential month-by-month moisture accumulation through air leakage and vapour diffusion, CMHC, 1998.
- *ASTM E783 Standard Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors*, American Society for Testing and Materials.
- *Structural Requirements for Air Barriers*, Morrison Hershfield for CMHC.
- *Field Investigation Survey of Air Tightness*, Air Movement and Indoor Air Quality in High-Rise Apartment Buildings, Summary Report, Wardrop for CMHC.
- *Air Permeance of Building Materials*, Air Ins for CMHC.
- *Airtightness Tests of Components Used to Join Different or Similar Materials Materials of the Building Envelope*, CMHC.
- *Commissioning and Monitoring the Building Envelope for Air Leakage*, Morrison Hershfield for CMHC.
- *Testing of Air Barrier Systems for Woodframe Walls*, Insitute for Research in Construction/ National Research Council Canada, 1988.
- *Air Barrier Update*, S.Marshall, J.Rousseau, R.Quirouette, CMHC, 2000. Continuing education arcticle @ http://www.cmhc-schl.gc.ca/research/highrise/
- *CMHC's Best Practice Guides:* @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_guides.htm

WETTING OF BUILDING ENVELOPES

THE ISSUES

Wetting of the building envelope is one of the leading causes of deterioration of cladding systems. Water saturation of cladding materials can result in a range of destructive mechanisms including cracking, movements, corrosion, decay, leaching, and efflorescence. In addition the presence of water on exterior assemblies is a key condition for water penetration of envelope assemblies and building interiors. Reduction or elimination of wetting of exterior cladding is an effective means of reducing the potential for leakage to envelope assemblies and the building interior.

DESIGN CONSIDERATIONS

Water deposited on the face of the building will tend at first to be absorbed by porous materials such as concrete, masonry and mortar. As the rate of deposit exceeds the rate of absorption, water begins to migrate down the wall.

Recent observations and tests conducted for CMHC have confirmed that the deposit of rain resulting in wetting of the face of the building is not uniform. Owing to the deflection of wind-driven rain, moisture deposition is up to 20 times greater at the top and upper corners of an exposed building face than on the remainder of the wall. Selective use of higher performance cladding materials and assemblies at these locations may be an effective strategy. In addition, if wind-driven rain can be deflected and prevented from wetting the upper portions of a building, lower wall areas may also remain dry.

Traditional buildings are characterized by deep cornices, projecting sills, and other architectural water-shedding features. These features were successful in preventing large scale wetting of the building envelope, slowing building deterioration. More recent buildings have relatively unarticulated surfaces that often do not offer the same degree of protection.

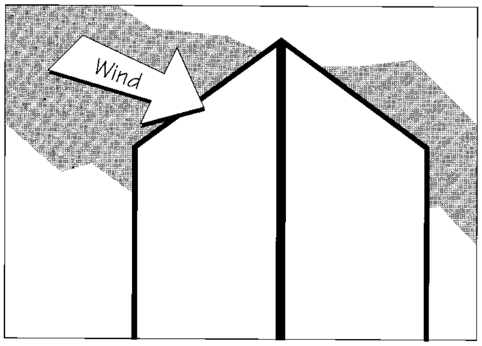
To prevent large scale wetting of the building envelope and thus increase durability, designers can consider architectural features such as:

- outward projection of the roof, cornice, or other rain deflecting devices,
- sills and drip ledges to take water away from wall surfaces,
- moisture resistant materials (reduced porosity) where wetting is greatest,
- incorporate wind deflection for building orientations most subject to wind driven rain.

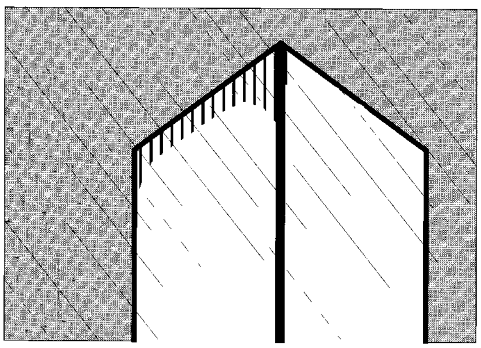
RETROFIT OPPORTUNITIES

Retrofit or renovation of existing high-rise buildings provides an opportunity to address excessive wetting of facades. Existing wetting patterns should be carefully documented and analyzed. Modifications to the form of the building, particularly at the wall and roof interfaces and at upper level corners, can be introduced to prevent wetting. Modifications may include the addition of cornices, roof overhangs or other elements to deflect wind. Providing additional protection from wetting is particularly useful if moisture sensitive materials and components are located in high exposure areas of the building.

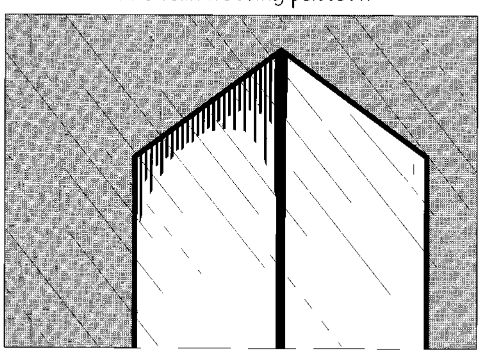
Wetting Patterns on Typical Multi-Storey Building



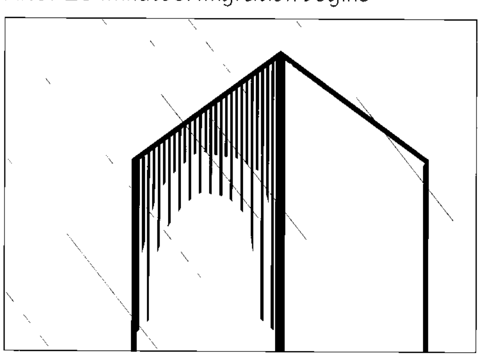
Dry building



After 10 minutes: development of characteristic rain wetting pattern



After 20 minutes: migration begins



After 40 minutes: rain ends, wetting of windward faces by deposit and migration roughly proportional to directional exposure to driving rain

Sources of Information

- *Simulation of Wind-Driven Rain and Wetting Patterns on Buildings*, The Boundary Layer Wind Tunnel Laboratory, University of Western Ontario for CMHC.
- *Wind-Driven Rain Study for the Governor's Road Project*, Horia Hangan and David Surry, University of Western Ontario Faculty of Engineering Science for CMHC, 1999.
  @ http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/99106.htm
- *Wind Driven Rain and Buildings*, National Research Council Canada, 1975.
- *Rain Penetration Control*, Morrison Hershfield for CMHC, 2000.
- *CMHC Best Practice Guides:*
  @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_guides.htm

PRESSURE EQUALIZED RAINSCREEN (PER)

THE ISSUES

Rainscreen walls are assemblies that provide a cavity behind the exterior cladding. The principal function of the cladding is to deflect intruding rainwater without damage to moisture sensitive materials within the wall assembly. However, water that is present on the outer face of the cladding, may enter the cavity as a result of a number of forces, including momentum, surface tension, gravity and air pressure differences. The cavity acts as a capillary break to prevent water reaching the remainder of the wall assembly. The cavity also acts as a drainage space to shed moisture to the exterior by means of flashings and vents provided at the bottom of each cavity compartment.

Pressure equalized rainscreen (PER) wall assemblies attempt to reduce water penetration of the wall assembly as a result of pressure differences. Wind forces create in higher air pressures on the exterior of the wall than within the building or the wall assembly. Air movement in response to this pressure difference can transport moisture present on the exterior of the cladding into the wall.

PER wall systems and assemblies require that they be designed so that the pressure difference across the exterior cladding is nearly zero at all times. This reduces the driving force associated with pressure differences, and prevents moisture from moving through the wall assembly. The air barrier, in conjunction with a vented and compartmented cavity, acts to reduce or eliminate air pressure differences across the cladding.

The control of airflow is inherent in the PER wall systems and assemblies. If the airflow through and within the fabric of the wall is not controlled, the air pressure difference across the rainscreen (or outer section of the wall) cannot be equalized.

Even with the best design concept and construction practices, however, there is always the possibility that some water will find a way inside the wall cavity. Therefore, the wall system also has to contain features that will drain this water to the outside. As in a rainscreen assembly, any incidental water which may enter the cavity is drained to the outside by means of the cavity and flashings.

At any time, the air pressure loading on walls varies significantly from one location to another. As wind loads change, positive pressures are created on some areas of the building envelope and negative pressures on others. It is necessary to divide, or compartment, the cavity into smaller areas. In this way, the range of pressure differences acting on each compartment can be significantly reduced.

The design parameters for PER wall systems are still in development. Considerable research information on this subject, however, is now available from a number of Canadian organizations.

Rainscreen walls require certain design features in order to achieve pressure equalization under dynamic wind conditions. To obtain pressure equalization across the rainscreen, the airflow through the wall system and the lateral air flow within the wall cavity must be controlled. The design of the wall system must include:

- Air Barrier Systems
- Sealed Compartments
- Appropriate Venting
- Quality Control

DESIGN CONSIDERATIONS

Air Barrier Systems

The importance of the air barrier system to effective building envelope performance has been discussed earlier in this section. Air barriers are particularly important in pressure equalized rainscreen wall assemblies.

The wall system must contain a continuous and durable air barrier that controls airflow through the wall. The air barrier system must be made of structural elements, or be supported by structural elements capable of resisting wind loads. The air barrier system should be rigid to minimize material fatigue, especially at the points of attachment to the structure.

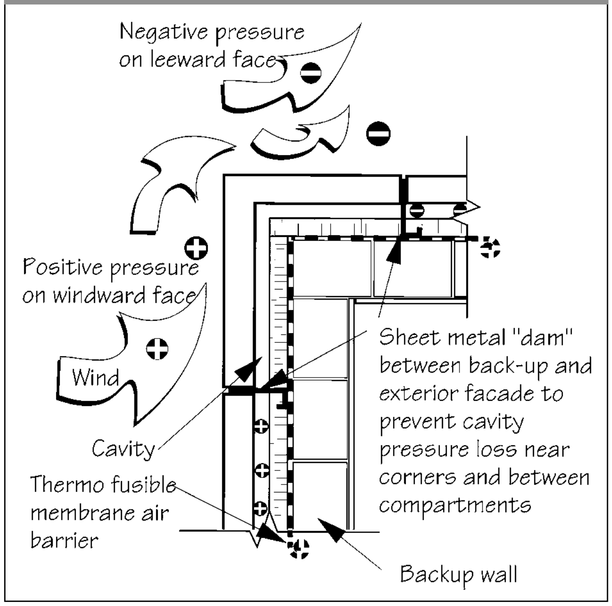
Sealed Compartments

Air pressures induced by winds vary over the width and height of the building. Steep gradients can develop towards the corners and the roof line while pressures can be fairly uniform near the centre of the walls. These pressure differentials can induce lateral airflow within the cavity unless interrupted at suitable intervals by sealed compartments. The frequency of these cavity compartments should be such that the air pressure within any compartment can be nearly instantaneously equalized with the exterior pressure.

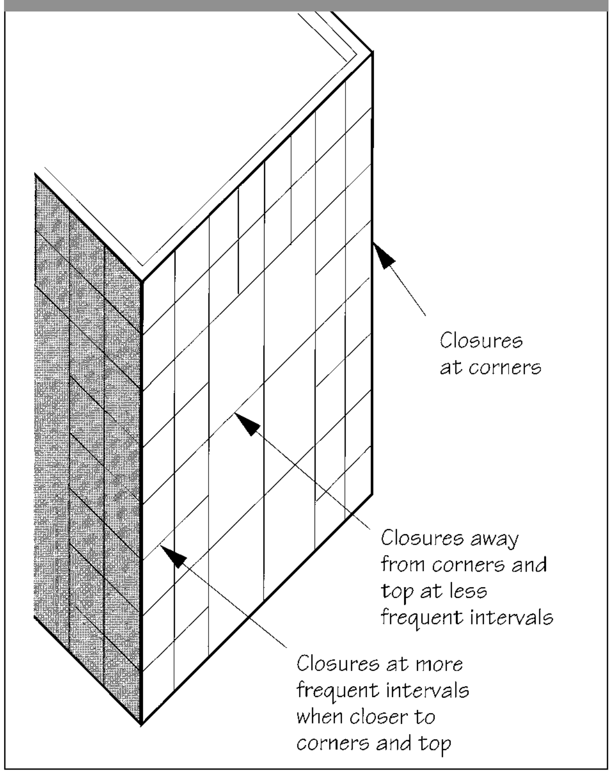
The size of the compartments should vary over the face of the wall, with larger compartments located at the centre where pressures gradients are lower, and relatively smaller compartments located at higher pressure gradients locations near the building edges. Cavities must be closed at the corners because wind flowing around the building produces high pressure differences at these locations. Specific design guidelines include:

- the cavity depth should be at least 25mm,
- the cavity should contain sealed compartments at each corner and at 1.2m intervals for 6m from the corners and the top,
- sealed compartments located at the centre of the wall in both directions at every 3m to 6m.

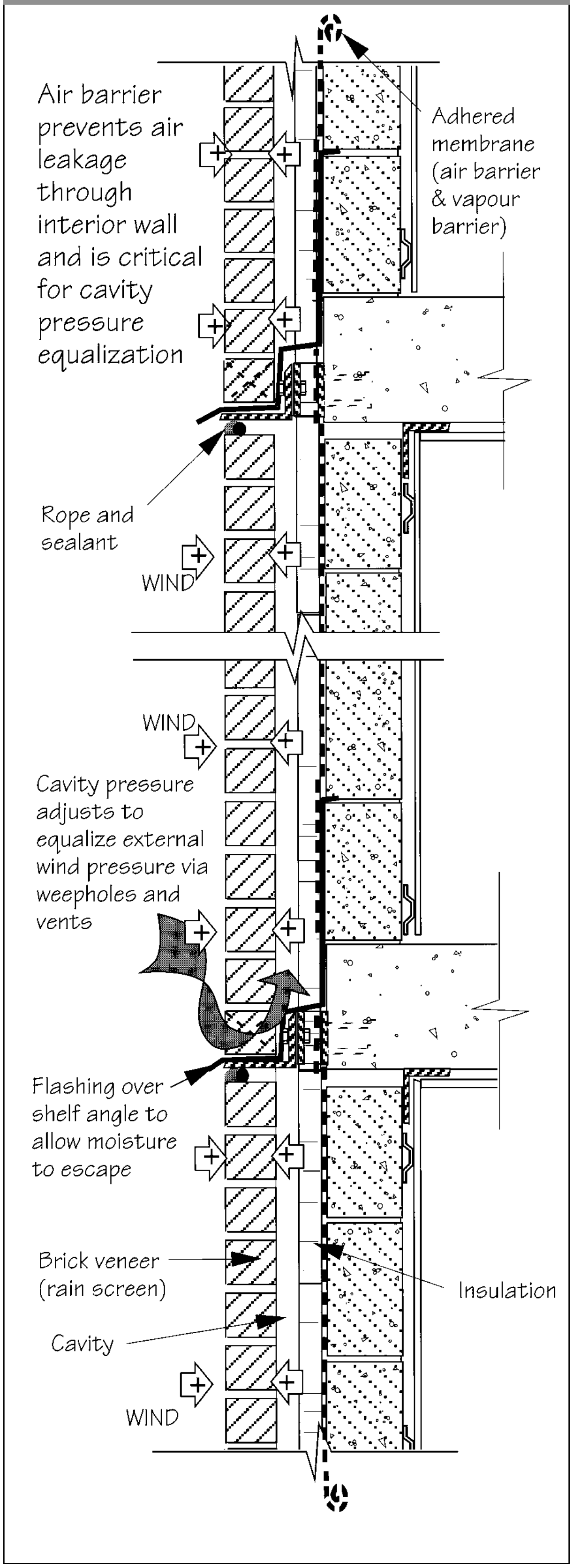
Corner Compartmentalization Options



Closure Distribution for Pressure Equalized Rainscreen



Pressure Equalized Rainscreen Wall



Venting

Sufficient venting is required in the pressure equalized rainscreen to ensure that cavity air pressure is quickly equalized to the outside pressure. The location and size of vents must allow air to flow into and out of the cavity, thereby achieving pressure equalization across the rainscreen. The effective area and location of the vents should be based on the envelope air leakage and the cavity volume.

The stiffness of the outer wall layer and air barrier system will affect the volume of the cavity and must be taken into account when designing the venting requirements. Venting must also be provided at locations that will facilitate drainage of the cavity.

- Vent holes should be at least 10mm in diameter to prevent blockage.
- To obtain pressure equalization of the rainscreen, a rule of thumb is the venting area should be 25 to 40 times larger than the leakage area.
- Care must be taken in masonry construction to ensure that vents are not blocked by mortar.

Asymmetrical Venting

Appropriate sizing and location of vents can provide an additional means of improving rain penetration resistance. The asymmetrical venting concept is based on concentrating vents in places where the wind pressure on the face of compartment is greatest. This has the effect of raising cavity pressure so that most of the compartment experiences an outward pressure. The raised cavity pressure forces water out of leakage paths rather than in. Asymmetrical venting is achieved by concentrating the required vent area on the side of the compartment closest to the centre of the façade.

Quality Contol

The quality control and commissioning process has been discussed previously in the Air Barriers section. A similar process should be applied to other envelope systems including pressure equalized rainscreens.

The commissioning of a rainscreen wall will verify building performance objectives before completion of construction. This is accomplished through performance engineering and field or laboratory testing. To assist with performance engineering, CMHC has developed a computer program (RAIN) that simulates the pressure equalization (P.E.) performance of any design.

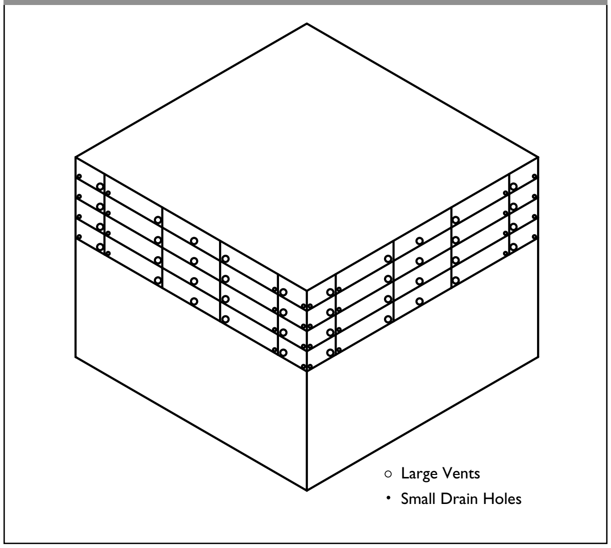
The quality control process for pressure equalized rainscreen walls should include:

- determining that facade areas and windows to be designed as pressure equalized rainscreens,
- locating vertical and horizontal compartments and determining the number of rainscreen cavities,
- developing basic design of wall or window system to include an air barrier system, compartment seals, and cladding system with vents/drains,
- determining physical attributes to each rainscreen cavity i.e. volume, vent area, leakage area, and stiffness of cladding and air barrier systems,
- simulating the performance of each rainscreen cavity using CMHC's "RAIN" **Rainscreen 2.1** and iterate the design until performance attributes are attained (90% pressure equalization),
- constructing a mock-up to test the P.E. performance of a design at pre-construction,
- assessing the complete design of envelope and preparing construction documentation,
- preparing a tender package requiring on-site mock-up test to verify field performance and workmanship quality,
- complete testing of rainscreen wall and window system, correct problems as required, and report results,
- ensuring rainscreen P.E. performance complies with design objectives and certifying that workmanship as complies with drawing and specifications,
- providing design information necessary for proper maintenance of walls systems.

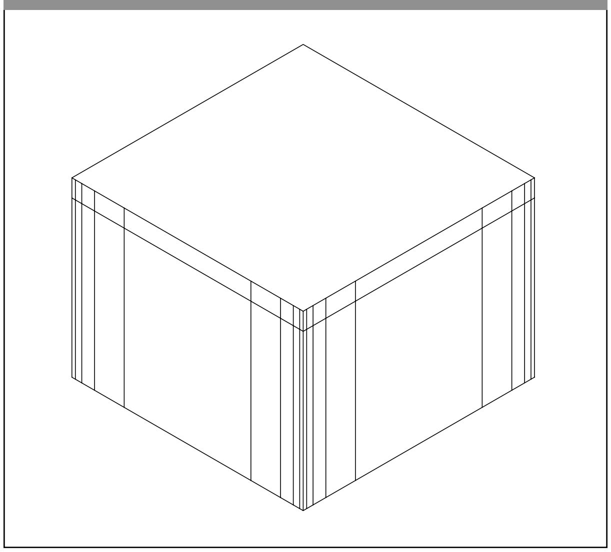
RETROFIT OPPORTUNITY

PERs should be used in all high-rise retrofit or recladding projects. In addition to providing an appropriate level of water management performance, rainscreen assemblies also include an effective air barrier and offer an opportunity to add additional insulation to the exterior of the building. Changing from face-sealed walls to raiscreen assemblies may result in additional wall thickness. Careful detailing will be required at interfaces with components such as windows and other penetrations. In many older buildings replacing windows at the same time as recladding will allow for correct detailing of interfaces with walls and will also improve overall envelope thermal performance. High-rise envelope retrofit projects will often involve scaffolding of the building exterior. The cost of providing access in this manner is expensive; upgrading all envelope assemblies and components at one time may result in lower life-cycle costs.

Asymmetrical Venting Concept



Developed Compartmentalization Plan



Sources of Information

- “The Rain Screen Wall”, Kerr D.D., in *Progressive Architecture*, pp.47-52, August 1990.
- *Pressure Equalization and the Control of Rainwater Penetration*, National Council Canada, NRCC33112.
- *A Study of the Rainscreen Concept Applied to Cladding System on Wood Frame Walls*, Morrison Hershfield for CMHC.
- *Rain Penetration Control Guide*, Morrison Hershfield for CMHC, 2000.
- *RAIN Rainscreen 2.1*, a computer program to aid in designing Pressure Equalized Rainscreen Walls, CMHC.
- *The Rainscreen Wall: A Commissioning Protocol*, Quirouette Building Specialists for CMHC.
- *Laboratory Investigation and Field Monitoring of Pressure Equalized Rainscreen Walls*, Quirouette Building Specialists for CMHC.
- *Testing Rainscreen Wall and Window Systems: The Cavity Excitation Method*, Quirouette Building Specialists for CMHC.
- *CMHC Best Practice Guides:* @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_guides.htm
- *Further Research:* @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_rdhigh.htm#rain

EXTERIOR INSULATION AND FINISH SYSTEMS (EIFS)

Related Topics

Building Envelope
Space Heating and Air Conditioning

THE ISSUES

Exterior insulation and finish systems (EIFS) are light weight exterior cladding systems consisting of insulation board mechanically and / or adhesively attached to a wind load-bearing substrate, and covered with an integrally reinforced base coat and a protective surface finish. EIFS are based on the concept that optimal wall performance is achieved when all of the temperature and moisture sensitive components are placed on the interior side of the insulation. To protect the insulation from the environment while providing an architecturally pleasing finish, the insulation must be coated with a thin finish layer. This layer needs to be reinforced to resist cracking from temperature, wind and structural movement.

The use of a source drained[1] barrier approach to moisture management is considered the minimum for best practice for EIFS and is an essential component of any EIFS assembly. Moisture barrier protection of the substrate, drainage and ventilation strategies may also be required depending on particular project and climatic conditions.

Advantages of EIFS include:

- location of the insulation protects the primary structure from temperature extremes and moisture-related damage,
- exterior insulation, particularly in steel framed buildings, can result in energy savings, and reduced cost of HVAC equipment,
- complex surface features are possible in a wide range of finish colours and textures,
- smaller dead loads and reduced structural costs,
- thinner walls will increase usable area and reduce building footprint,
- an EIFS can be pre-manufactured in tranferrable panels.

Disadvantages include:

- sensitivity to deficiencies in workmanship, particularly at joints penetrations and sealants,
- susceptibility to mechanical damage.

Consideration should also be given to three key elements of EIFS:

- Rain Penetration at Joints
- Interstitial Condensation
- Cracking of the Lamina

[1] Drainage to the exterior of water in the assembly should occur at the source of the water infiltration.

DESIGN CONSIDERATIONS

The most serious and widespread problems associated with EIFS relate to moisture damage, often to the substrate system or sheathing since EIFS themselves are made up of essentially moisture tolerant materials.

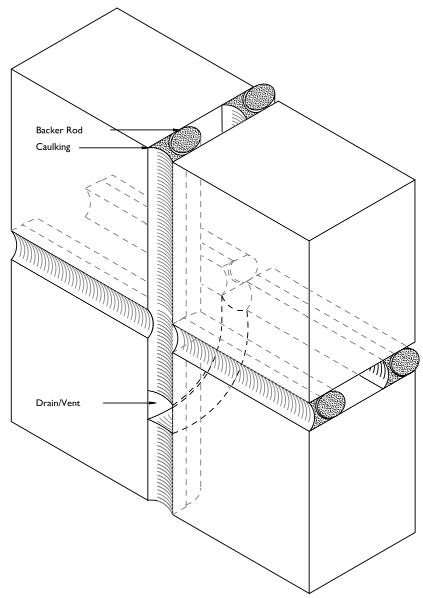
Rain Penetration at Joints

- Face sealed joints are not recommended; use 2-stage seals in joints that provide for water drainage at the source.

- A drained subsill under windows is essential in most applications.

- The EIFS finish should stop at least 8” above grade & a special system is required below grade. Manufactuers should be consulted for the appropriate details.

Rainscreen Joint Between Face-Sealed Elements



Interstitial Condensation

- Where possible, additional insulation should not be placed in the stud space. This will maintain the interior side surface temperature of the substrate sheathing above the dew point of the interior air. If insulation is required in the stud space a dynamic analysis for the prediction of condensation should be carried out prior to finalizing the design.

- A vapour barrier is required in EIFS clad walls. A membrane or trowel applied vapour barrier can be used between the insulation board and the sheathing. Alternatively, a separate vapour barrier on the inside of the wall can be provided.

Cracking of the Lamina

- Cracking caused by excessive stresses can occur as a result of inappropriate location of joints between insulation boards, or insufficient or inappropriate control and movement joint spacing and location.

- EIFS with thin glass-mesh reinforced high-polymer content laminas may experience durability and performance problems if the mesh is not properly embedded in a base coat of the proper thickness. The base coat provides the primary water penetration resistance, and when reinforced, the majority of the structural properties of the lamina.

Sources of Information

- *Exterior Insulated Finish System Labroratory Evaluation of Joints and Materials Subjected to Artificial Conditioning*, Lawrence Gibson for CMHC,1995.
@ http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/96230.htm

- *Exterior Insulated Finish System Field Performance Evaluation*, James Posey & John A. Vlooswyk for CMHC, 1993.
@ http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/98118.htm

- *Exterior Insulated Finish System*, Problems, Causes and Solutions, CMHC,1991.

- *EASE computer program to analyse condensation potential of wall systems*, CMHC.

PARKING GARAGES

Related Topics

Source Reduction

THE ISSUES

Parking structures are subjected to demanding service conditions. These include live load effects such as vehicular impact and abrasion as well as environmental effects such as high humidity and moisture levels, thermal variations, and attack from de-icing salts. Together, these factors can lead to premature deterioration of parking structures.

The primary cause of parking structure failure is attributed to corrosion of the reinforcing steel due to chlorine ions from road salts. The overall cost of repairs to parking structures in Canada is estimated at 1.5 to 3 billion dollars. Studies show that the repair costs for individual structures can exceed the original construction costs.

DESIGN CONSIDERATIONS

The 1995 NBC requires parking structures to be designed in conformance with CAN/CSAS-413-94, which requires measures to protect parking structures from the ingress of moisture and salts, the primary contributors to deterioration. Specifications are provided for protective membranes, and epoxy coatings of reinforcing bars are required for the various structural elements.

Designers and contractors should further mitigate potential problems by:

- ensuring positive drainage,
- by minimizing cracks in concrete,
- through careful placement of expansion and construction joints,
- through improved quality control during the application of surface protection systems.

Positive Drainage

Parking slabs must have adequate slope and properly positioned drains to ensure rapid run-off of water. A minimum slope of 2% is recommended.

Reduced Cracking

Concrete mix and placement procedures must be controlled to minimize shrinkage cracks. Shrinkage cracks must be treated prior to installation of surface protection systems.

Elevated Expansion and Construction Joints

Construction joints should be located at high points in the slab to prevent standing water on the joints. Jogs in joints should be minimized at the design stage. It is important to ensure joint widths in expansion joints are adequate to accommodate structural movement and to prevent concrete damage.

Surface Protection

The performance of surface protection systems depends on a number of factors:

- proper mixing of components in accordance with manufacturers recommendations,
- timely application of the mixed components,
- proper preparation of the concrete surface,
- avoidance of excess surface moisture in the concrete,
- curing of membrane under appropriate temperature conditions,
- protection of the membrane until proper curing is achieved.

Special attention should be paid to roof slabs of underground parking garages as they are often buried beneath paving and landscaping materials, making the top surface of the concrete inaccessible for routine inspections.

Fly Ash

The manufacture of cement, one of the constituents of the concrete used in parking structures, results in large emissions of CO^2 a key greenhouse gas. Emissions of CO_2 result both from the use of fossil fuels during the cement manufacturing process, and from the process itself. Production of one tonne of cement releases 1.25 tonnes of CO_2, approximately 0.75 tonnes from energy use, and 0.5 tonnes from the calcinating of limestone during manufacture.

Replacing a portion of the cement with fly ash, a by-product of coal burning power plants can reduce the environmental impacts of concrete use. Fly ash has traditionally been added to concrete mixes in quantities up to 15%. However it is possible to use larger volumes, up to 70% for some applications, in place of cement. The addition of fly ash enhances many of the qualities of the finished concrete, making it stronger, less permeable to water, and more durable. While workability and pumpability are also improved, concrete containing high volumes of fly ash does take longer to set and gain initial strength. For this reason it is not suitable for applications where rapid removal of forms is required.

Fly ash is less expensive than concrete and its use can result cost savings, although mixes using fly ash may require additional admixtures reducing potential savings.

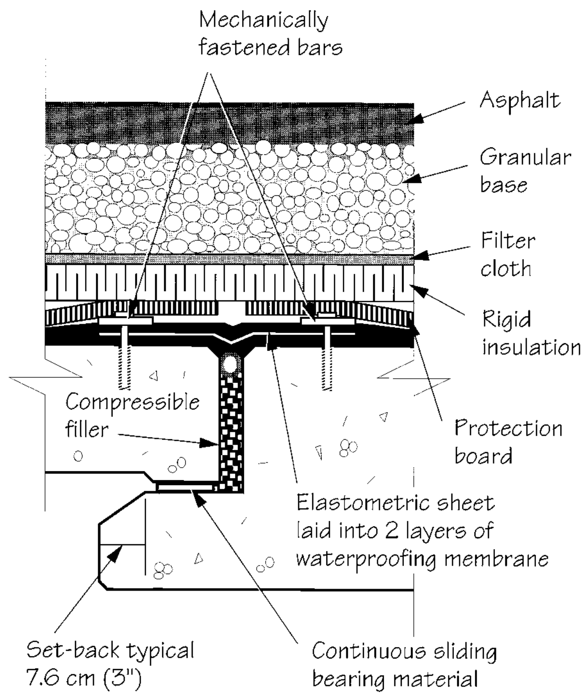
RETROFIT OPPORTUNITY

Renovation of parking garages typically involves localized repair of deteriorated concrete and replacement of corroded steel reinforcing.

Sources of Information

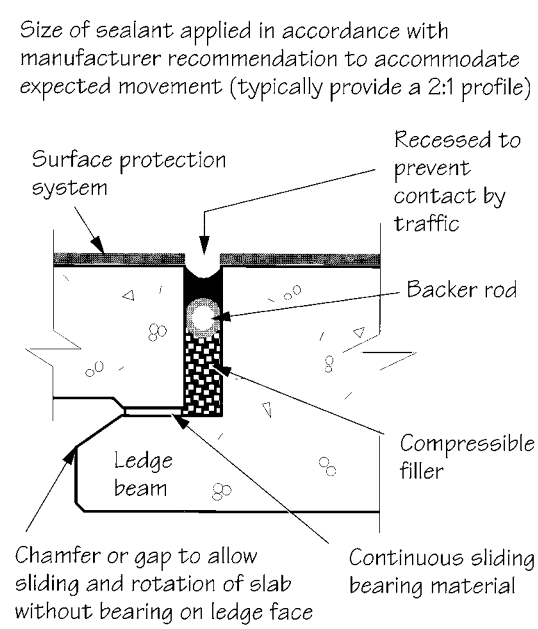
- CAN/CSA Standard S-413-94 "Parking Structures".
- *Summary of Concrete Findings*, CMHC, 1994.
- *Effective Installation of Membranes on Parking Garage Decks*, Construction Technology Update No. 29, Mailvaganam N.P. and P.G. Collins, NRC 1999.

Expansion Joint at Parking Level



Source: Menkes Developement / Tridel

Expansion Joint at Underground Roof Slab



Source: Menkes Developement / Tridel

LOW SLOPE ROOFING SYSTEMS

Related Topics

Landscape Practices

THE ISSUES

Sloped roofs have typically not been used on high rise buildings. They may, however, provide improved performance when compared to flat roofs, and their use should be considered. Flat roofs, or more properly low-sloped membrane roofs, are the most common roofing assembly used on high rise buildings. When properly designed and constructed, low slope membrane roof systems should be capable of lasting in excess of 20 years.

There are two basic low-slope roofing assemblies, both of which have 3 basic components: a membrane, insulation, and a structural substrate (a vapour retarder is also sometimes required, particularly in high humidity buildings in cold climates). The assemblies differ primarily in the location of the membrane relative to the insulation layer. In a conventional assembly, the membrane is located above the insulation layer and is exposed to all environmental loads. In a protected membrane assembly, the membrane is located below, and is protected by the insulation layer. An additional ballast layer is required to hold the insulation in place.

Various membranes may be used on low-slope roofs. The principal types are:

- Asphalt based membranes
- 1 Built up roof (BUR)
- 2 Modified bitumen (SBS)
- Polymer based membranes
- 1 Thermosetting - EPDM
- 2 Thermoplastic - PVC

Failure mechanisms vary depending on the type of membrane. Blistering and ridging are problems with BUR and SBS roofs, lap defects can affect SBS and EPDM membranes, while embrittlement and shrinkage can cause failures in PVC.

Water leakage is the most obvious indicator of failing roof systems. Thermography may be useful in identifying areas of wet insulation in most conventional roof assemblies, although the applications of this process are somewhat limited.

Improved practice would include running the roof membrane to extend over the parapet. Metal counter flashing can then ensure that leakage into or around the parapet is restricted. Careful detailing and installation of all penetrations through the membrane (plumbing stacks, fireplace flues, exhaust fans, etc.) is required to prevent leakage. Other important considerations include:

- Seams
- Membrane Moisture
- Ballast
- Standing Water

DESIGN CONSIDERATIONS

Seams

Detailing and construction of seams in sheet materials can also result in leakage. Most of these problems occur as a result of deviations from manufacturers' recommended installation procedures.

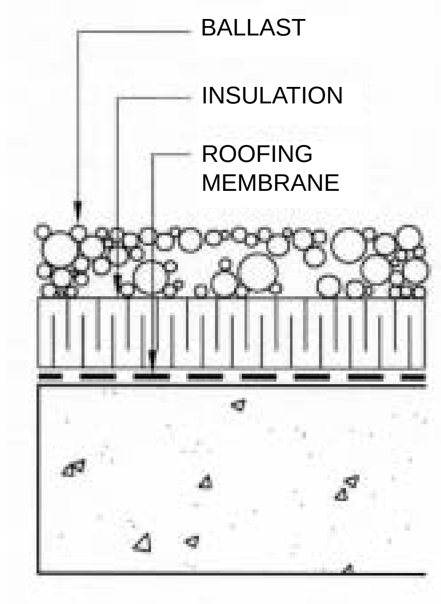
Membrane Moisture

Moisture accumulating underneath the membrane can also result in delamination of the membrane from the roof deck and eventual leakage. This moisture can be the result of air leakage and moisture migration from within the building, especially around plumbing stacks, and through penetrations provided for mechanical equipment. Continuity of the air barrier must include appropriate detailing of roof assemblies.

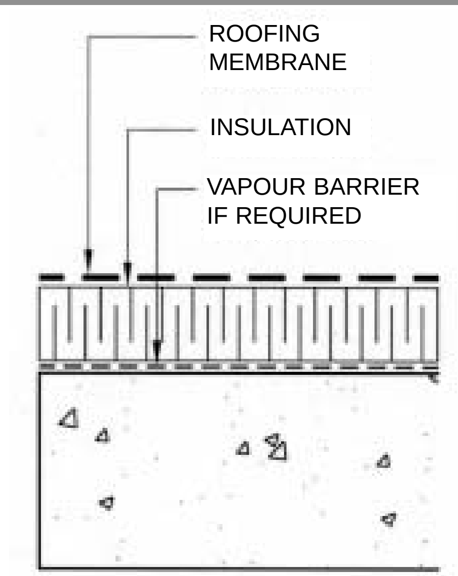
Inadequate Ballast

Inadequate ballast can result in floating and separation of insulation materials. Ballast settling between insulation (sheets as they float will disrupt continuity of the insulation and potentially damage the membrane). Many insulation products

Membrane Protected Roof Assembly



Conventional Roof Assembly



will also degrade when exposed to direct sunlight where ballast has been eroded. Providing shading for the roof will reduce the potential for sun damage while also reducing the cooling demand on the building HVAC system.

Standing Water

Standing water can significantly reduce the service life of many roofing membranes.

Providing adequate slopes to drains, and providing adequate numbers of drains, to eliminate ponding of water in low areas is essential. Drains should be provided at the low points of roofs. The effects of deflection of structural members should be taken into account in locating drains and in calculating slopes. Drains should always incorporate guards to prevent clogging by leaf and other debris.

Green Roofs

The benefits of using green roofs are discussed in Section 4: Environmental Performance of this document. Appropriate membrane selection is important. The membrane should be durable and should be root-resistant. Water testing of the membrane before application of the growing medium is recommended. A protection layer or drainage composite panel should be provided. Plant material should be carefully selected and a landscape architect should advise on expected plant growth and maintenance requirements.

Sources of Information

- *Roofs that Work,* National Research Council Canada, 1990 BSI-89 (NRCC-31512)
- *The Manual of Low-Slope Roof Systems,* C.W. Griffin & Richard Fricklas, McGraw-Hill 1996
- *Roofing Practices Manua*l, Canadian Roofing Contractors Association.
- *CMHC Best Practice Guides: Flashings* @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_guides_flash.htm
- *CMHC EMPTIED Computer Application*
- *Design Guidelines for Green Roofs,* CMHC Steven Peck, Monica Kuhn www.cmhc-schl.gc.ca/en/imquaf/himu/himu_002.cfm

REGIONAL DIFFERENCES

Air Barriers

An effective air barrier system is essential in all climatic regions. In cold climates the air barrier plays a key role in improving energy efficiency by reducing leakage of heated air from within the building, and preventing infiltration of cold air.

In wet climates, in addition to improving thermal performance, the air barrier, acting as part of a pressure equalized rainscreen system, helps to reduce water penetration of the envelope and building interior. If a membrane type air barrier is located on the exterior side of a wall assembly it may also function as a secondary waterproofing layer.

In addition an air barrier, the National Building Code requires that a vapour barrier be provided to prevent the diffusion of vapour from within the suite to locations where interstitial condensation may occur. Self-adhesive membrane air barriers are commonly used in high-rise construction. Membranes of this type function effectively to reduce air flow through the building envelope, however they are also impermeable to vapour diffusion. Depending on the locations of air and vapour barriers there is potential for moisture to be trapped within assemblies. The anticipated flows of heat and vapour, and the permeabilities of each layer in the assembly should be carefully analysed in order to prevent moisture related problems. CMHC’s EMPTIED computer program can be used to estimate the potential amount of moisture likely to accumulate and dissipate in a specified envelope assembly through air leakage and vapour diffusion.

It is possible to combine the functions of air and vapour barrier in one material and location. In this case the air/vapour barrier location relative to wall thermal insulation should be carefully considered in order to minimize the potential for interstitial condensation. It is important to ensure that sufficient insulation is placed on the exterior of impermeable air barriers to prevent the temperature of sheathing dropping below the dew point.

An ideal wall assembly, suitable for all climate zones, is an exterior insulation assembly with a single membrane providing the functions of air / vapour barrier, and secondary waterproofing layer. All of the required insulation is placed on the exterior side of the membrane and there is no insulation or separate vapour barrier placed on the inside of the wall.

Pressure Equalized Rainscreen

Pressure equalized cladding assemblies are appropriate for use in all climatic regions. While rainfall levels vary considerably across the country, exposure to wetting also varies with building height, and with issues such as the degree of protection provided by surrounding buildings and topography. In all regions high-rise buildings will be exposed to considerably more wetting than lower buildings. Pressure equalized walls are the most effective means of dealing with moisture management in high-rise buildings.

EIFS

Exterior insulation finish systems are used to best advantage in cold dry climates. The location of insulation on the exterior of wall assembly is an effective strategy for reducing thermal bridging in areas where heat loss through the envelope is of primary concern. Face seal assemblies are less appropriate for use in highrise applications. In wet climates, PER assemblies are vital.

Wetting Patterns on Buildings

Wetting of high-rise buildings is a function of both rainfall intensity and wind effects. Wetting will therefore occur in all climatic regions. Design of building elements to reduce exposure and minimize wetting is most effective in wet climates.

Parking Garages

Protection of parking garage slabs and structure from moisture is important in all climatic regions. Additional measures are required in cold climates where deicing salts are frequently used.

In This Section

Building Envelope
- windows & solar control
- air leakage
- insulation systems
- thermal bridging

Space Heating & Air Conditioning
- integrated design process
- electric heating systems
- natural gas heating
- HVAC distribution systems

Other Systems
- control systems
- individual suite metering
- motors
- auxiliary electric motors
- domestic hot water

Lighting & Appliances
- lighting
- appliances

Alternative Energy Supply Systems
- co-generation
- ground source heat pumps
- fuel cells
- solar energy
- daylighting
- passive cooling
- wind turbines

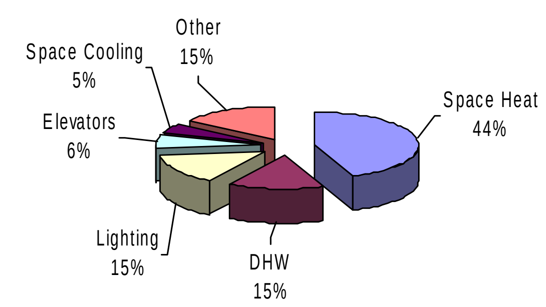
Case Studies

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.

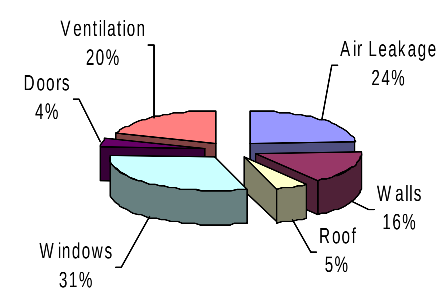
Advances to space and domestic hot water heating and distribution systems in high-rise buildings have not matched the efficiency improvements in low-rise residential buildings. Newer approaches

Typical High-Rise Residential Building End Use Energy Profile



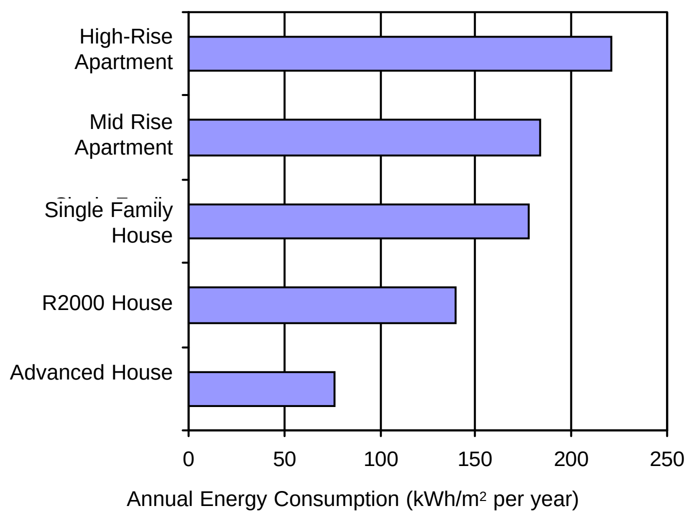
Source: Energy Audits of High-Rise Residential Buildings, CMHC, 1996

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

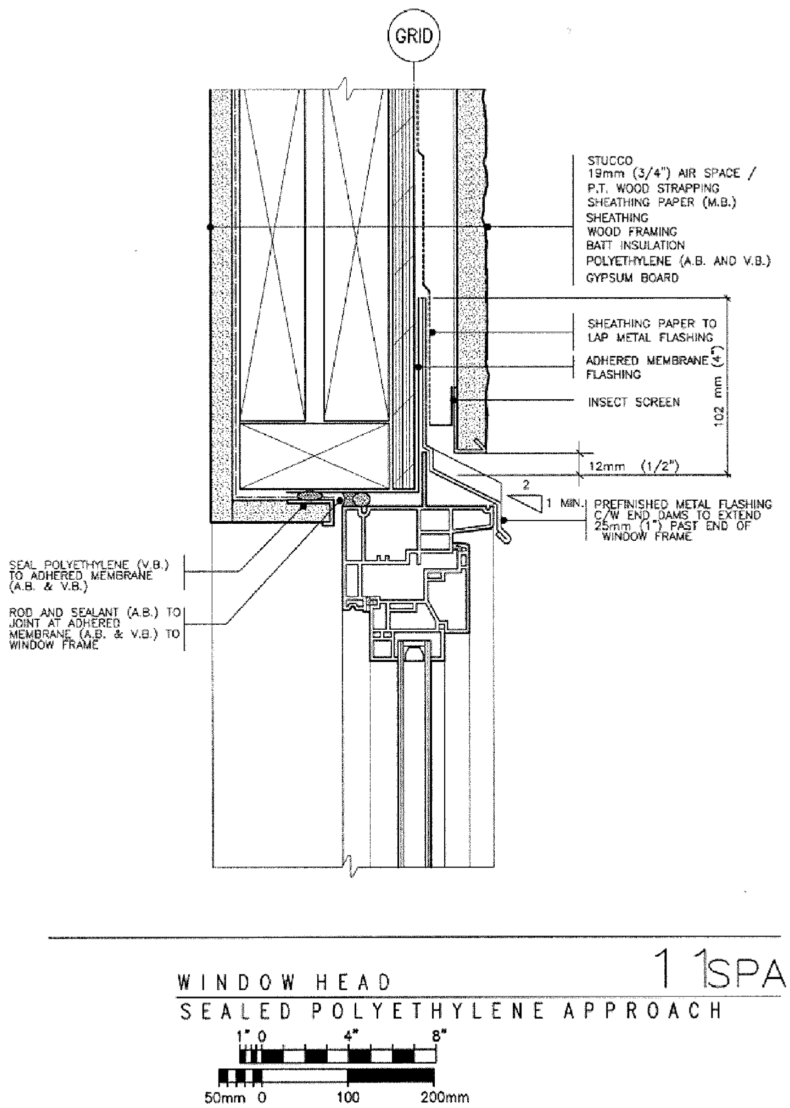
Windows and Solar Control

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



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.

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.

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.

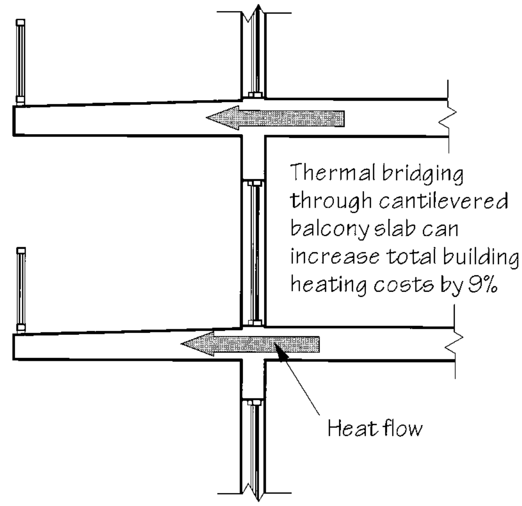
Typical insulation levels in Canadian high-rise buildings range from RSI 1.5 to 2.1 (R8 to 12) in walls, and RSI 3.5 (R20) in roofs. These insulation levels are below the levels commonly found in newer low-rise buildings, and are significantly below the levels recommended in the Model National Energy 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.

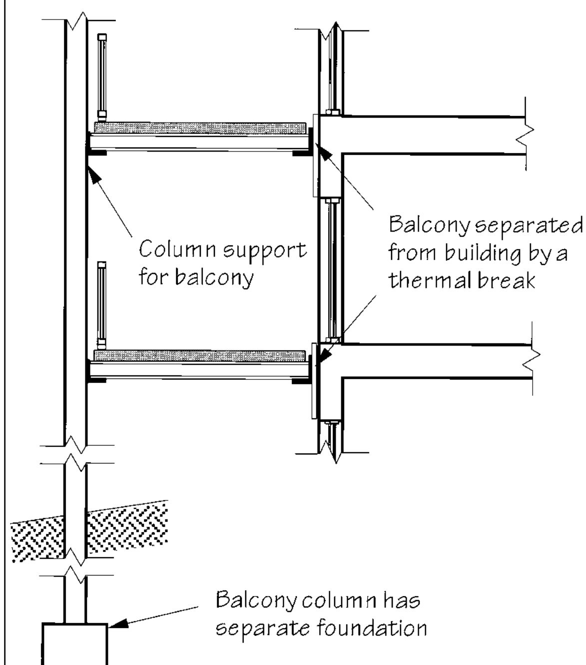
Insulation can generally be placed on the outside of the wall system, in the wall system, or on the interior of the wall system. The placement of insulation on the exterior of the backup wall, outside of the air barrier has the advantages:

- 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.

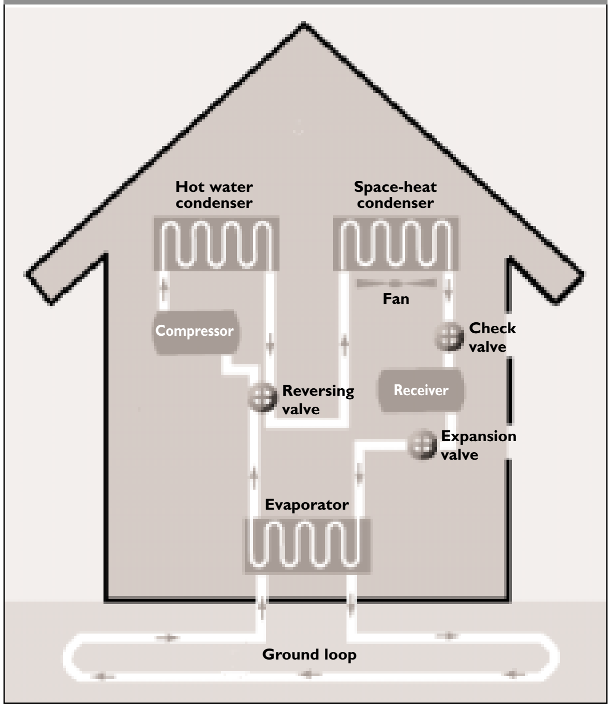
Designers and engineers should be aware of the issues and options concerning:

- 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)
- *Model National Energy Code for Buildings*, National Research Council of Canada.

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.

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, 2000.
- *HVAC Controls and Systems*, Levenhagen, J.I., Spethmann, D.H., McGraw Hill, New York, 1992.
- *HVAC Systems and Equipment Handbook*, 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)
- *Directory of Water Conserving Plumbing Fixtures*, International Association of Plumbing and Mechanical Officials, 1997. @ http://ww.iapmo.org

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.

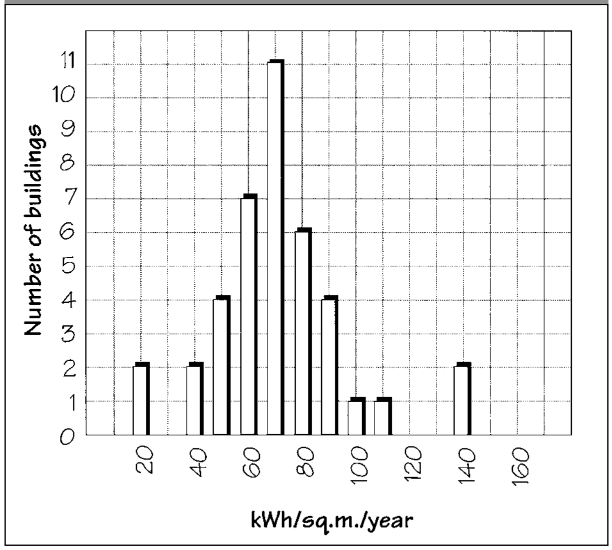
While lighting represents a large portion of electrical consumption costs, few designers and builders specify high efficiency lighting systems. As a consequence, higher operating costs are passed on to the building's occupants. Heat generated by lights (and appliances) is responsible for a significant 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.

Sources of Information

- *IES Lighting Handbook*, 8th Edition, Illuminating Engineering Society, 1993.
- 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)
- *2000 Energuide Appliance Directory*, Natural Resources Canada, 1-800-387-2000. @ http://energuide.nrcan.gc.ca/
- *Energy Efficient Lighting Products for Your Home*, Natural Resources Canada, 1-800-387-2000.
- *Consumer's Guide to Buying and Using Energy Efficient Household Appliances*, Natural Resources Canada, 1-800-387-2000.
- *Product Knowledge Guides*, Contact Local Provincial Electric Utility

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.

Sources of Information

- *Natural Ventilation in Non Domestic Buildings*, Applications Manual, CIBSE, 1997.

- *Daylighting: Design and Analysis*, Robbins, CL., Van Nostrand Reinhold, New York, 1986.

- Solar Energy Society of Canada Inc. @ http://www.solarenergysociety.ca/

- CANMET Energy Diversification Research Laboratory (CEDRL) of Natural Resources Canada @ http://cedrl.mets.nrcan.gc.ca/e/index_e.html

- 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

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

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/ft^2)	0.68 ACH
Corridors	0.2 ACH (0.026 cfm/ft^2)	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 à 1.89 ACH (0.11 à 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

ENHANCING INDOOR AIR QUALITY (IAQ)

In This Section

Source Reduction
- carpeting
- vinyl and sheet flooring
- paints and varnishes
- kitchen cabinets & bathroom vanities
- operations & maintenance

Mechanical Ventilation
- central vs. individual suite systems
- compartmentalization
- filtering of supply air
- reducing heating costs
- ensuring adequate airflow
- system control
- commissioning
- operation and maintenance
- some system options

Case Studies

Highrise residential buildings are often associated with poor air quality. Pollution levels within buildings are twice that of outdoors. Young children and seniors are particularly at risk because they spend the majority of their time indoors. Common occupant complaints include excessive humidity levels, lingering odours, and stuffiness in suites and corridors. Water penetration or condensation on interior finishes can lead to mold growth. Higher than acceptable CO_2 and particulate levels, and other pollutants from a wide variety of interior sources can also affect the health of building occupants.

Some building materials can release gaseous pollutants into the air. The emissions are generally higher in newly constructed buildings, but decrease overtime. Some materials, however, continue to emit low levels of pollutants over a long period (years).

Occupant usage can also affect indoor air quality. Smoking, cleaning products, room air deodorizers, personal cosmetics and hobbies can affect sensitive individuals. Cooking odours, and burning candles in an attempt to disguise cigarette smoke and other odours, are other sources. If ventilation systems do not isolate individual units from one another (or they are ineffective), these pollutants and odours can spill out to hallways and neighbouring units.

Occupant usage patterns can also contribute to excessive moisture generations in suites. High moisture producing activities include watering plants, cooking, bathing and clothes drying.

Building maintenance practices and materials used in cleaning, pest control and interior decoration can also effect air quality. Odours and contaminants associated with garages and garbage chutes can be problematic as well.

Ventilation systems in high-rise residential buildings do not always meet the standards of performance expected in low-rise buildings. In conventionally designed buildings, systems often are unable to deliver fresh air to, and remove exhaust air from, individual apartments. The result can be inadequately ventilated suites.

The strategy for achieving adequate indoor air quality in any building should involve:

- reduction and elimination of pollutants,
- exhausting pollutants that are generated at their source,
- sealing the partitions between units or providing air pressure to eliminate migration of pollutants and odours,
- supply and distribution of an adequate quantity of fresh clean air to meet the needs of occupants and dilute remaining pollutants.

Central to these strategies is the reduction of pollutants at their source, providing high-integrity spatial separation between individual apartments and common areas, and the design of a ventilation system which can supply an adequate rate of fresh outdoor air and exhaust or dilute pollutants. A good starting point is to look at examples of systems that work well in low-rise housing and can be adapted to high-rise buildings.

SOURCE REDUCTION

Related Topics

Mechanical Ventilation
Materials Selection

An effective design strategy will begin by eliminating the source of as many pollutants and contaminants as possible at the building design stage. Air quality can then be enhanced through effective ventilation systems—exhausting pollutants at source and ensuring the supply of filtered fresh air to all rooms in each suite.

THE ISSUES

Increasingly we are seeing more manufactured building products used in residential construction and furnishings, as opposed to "natural" products. Manufactured products often contain materials and compounds that can emit (off-gas) noxious or toxic pollutants into the air. Off-gassing generally decreases over time, but in some cases it can increase with changes in environmental conditions. The amount of pollutants emitted is dependent upon the amount of material and the amount of noxious substance in that material.

As the population spends more and more time indoors, and more homes act as offices, our exposures increase. Designers have to be more aware of the potential IAQ implications of materials. They need to be aware of practices to reduce pollutant emissions by limiting the amount of material and/or how to select appropriate materials and finishes. Alternatives are not always evident or available, however, and designers need to stay informed about source suppliers.

The most common types of detrimental contaminants emitted into the air from building materials are:

- Volatile organic compounds (VOCs)—found in oil-based finishes, vinyl flooring materials; carpeting, and other materials,
- Formaldehyde and other gases—found in glues used in manufactured wood products and many other materials.

DESIGN CONSIDERATIONS

The following sections discuss the implications of some standard building materials and finishes on IAQ and some potential methods to limit that impact.

In general:

- avoid using materials that off-gas noxious or toxic substances,
- limit the amount of pollutant emitting materials,
- be prepared to incorporate mechanical ventilation in order to solve IAQ problems.

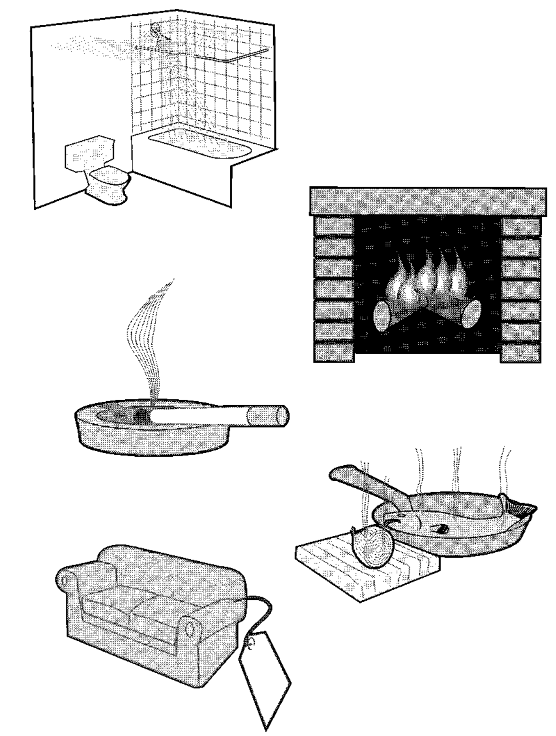
Carpeting

Typical carpeting uses latex as a binder in carpet backing, and numerous anti-static and stain chemical treatments on carpet fibres. Carpets also collect dust and dust mites. Most underpadding materials produce chemical emissions and also represent dust and mould collecting surfaces.

Off-gassing from carpets can be reduced by specifying lower emission carpeting materials. The Canadian Carpet Institute (CCI) has adopted the labelling program of the U.S. Carpet and Rug Institute (CRI). A CCI/CRI-IAQ label indicates that the product has passed a test for total emission of volatile chemicals of less than 0.6 milligrams per square meter per hour (0.6 $mg/m^2/hr$). CCI has also developed carpet installation guidelines for installers and maintenance guidelines for occupants to reduce IAQ problems associated with carpeting.

Off-gassing from carpets can also be reduced through specifying natural fibre carpets such as wool, and through the elimination of carpeting altogether by specifying hard flooring. However, when selecting hard flooring, it is important to

Contaminant Sources in Residences



consider noise concerns (see Occupant Comfort in Environmental Performance). To reduce off-gassing from glues, mechanical nailing strips are preferable to gluing of carpets.

Carpet, underpad and other materials such as drywall. can also absorb pollutants from other sources and emit them over time. Therfore, even when a low emission carpet is chosen, if other high emission materials or finishes are used in the building, it could become an emitter of pollutants over time.

Vinyl and Sheet Flooring

Vinyl composition tiles have lower vinyl content and produce fewer odours than sheet vinyl. Most adhesive materials contain volatile solvents. Water dispersion adhesives or pre-adhesive options are preferable. Compatibility of the adhesive with each flooring product must be confirmed with the manufacturer. Vinyl flooring can also be replaced with low emission materials such as ceramic tile.

Paints and Varnishes

Water-based paints and urethanes (for floor finishes) are generally available and are preferable to solvent-based materials. Suitable products are listed under the Environmental Choice Program and are recognized by their Ecologo™ symbol. Water-based finishes should be evaluated in relation to durability.

Kitchen Cabinets and Bathroom Vanities

Urea-formaldehyde resin is found in most glue used to make particleboard, plywood, and other glued manufactured wood products. All surfaces and edges of particleboard should be sealed with a low-toxicity sealer. Better choices are solid wood, or materials using formaldehyde-free glues such as fiberboard or plywood/particleboard meeting the E-1 European Standard.

Operations and Maintenance

Smoking in common areas must be restricted. Building maintenance plans should also consider reducing the toxicity of cleaning materials and products. Ensure that access is provided for maintenance and cleaning of ventilation filters and ducting to eliminate the accumulation of particulate and to prevent mold growth. An effective air barrier, and depressurisation of parking garages, must be provided to prevent the intrusion of gases from vehicles into the occupied spaces of the building. Pests such as cockroaches, can be controlled with methods that minimise the use of toxic pesticides, such as an integrated pest management method (see Farewell to Cockroaches under Sources of Information) as well as by the proper sealing of suites.

RETROFIT OPPORTUNITIES

There are many instances where the source of pollutants can be reduced by using low emission materials and finishes during equipment replacement or when suites are being renovated. Opportunities include:

1 Carpeting can be replaced with hard flooring or low emission carpeting when worn out flooring is being replaced.

2 Low emission paints and finishes can be used during repainting and renovation.
3 Cabinets and vanities can be replaced with those made from low emission materials during equipment replacement or renovation.

Sources of Information

- *Exposure Guidelines for Residential Indoor Air Quality*, Health Canada, 1995.

- *Building Materials for the Environmentally Hypersensitive*, CMHC, 1994.

- *The Clean Air Guide*, CMHC, 1993.

- *Healthier Indoor Environments: Canadian Sources of Residential Products and Services*, CMHC, 1994.

- *Farewell to Cockroaches: Getting Rid of Cockroaches the Least Toxic Way*, CMHC, 1998.

- Environmental Choice Program @ http://www.environmentalchoice.com/

MECHANICAL VENTILATION

Related Topics

Space Heating and Air Conditioning

THE ISSUES

Occupants of high-rise residential buildings often complain of inadequate, excessive, or poorly-controlled ventilation rates. Common occupant complaints resulting from inadequate ventilation include excessive humidity levels, condensation on exterior windows and walls, lingering odours and stuffiness in suites and corridors. Common occupant complaints resulting from excessive ventilation include discomfort from drafts, dry air, and high heating or cooling costs.

Most high-rise residential buildings do not have mechanical ventilation systems to supply air to occupants. Typically, corridor pressurisation systems are installed that control the transfer of odours between suites and provide makeup air to replace air exhausted by kitchen and bathroom exhaust fans. Ventilation air for occupants is intended to be supplied by natural ventilation through openable windows and infiltration through the building envelope, and in some cases by makeup air provided by the corridor pressurisation system.

Recent research has shown that these corridor pressurisation systems often do not perform as intended due to two main factors: lack of envelope airtightness and the strong stack effect in tall buildings. Whether or not corridor pressurisation systems are intended to provide ventilation for occupants, suites in many high-rise residential buildings have been found to be over-ventilated, under-ventilated, or to receive stale ventilation air from other parts of the building during the heating season when windows are closed.

Excessive infiltration rates commonly occur due to wind and stack induced infiltration through leaks in the building envelope and between floors. Common locations where excessive ventilation occurs include lower suites subjected to high stack pressures on cold winter days, and windward facing suites on windy days. Insufficient ventilation rates commonly occur on upper floors and on leeward facing suites due to inhibited or reversed ventilation airflow.

A number of other problems are also common in high-rise residential mechanical ventilation systems. In many instances, exhaust fans are not capable of moving a sufficient amount of air, and frequently their operation is so noisy that occupants do not use them. Backdrafts and noise can also result in occupant tampering.

Ventilation air intakes located close to contaminant sources such as fireplace and boiler fumes, plumbing stacks, garbage room vents, and so oncan seriously affect indoor air quality, as can air migration from underground parking facilities. Where corridors are not pressurised or inadequately pressurized, odours can move from suite to suite.

A main obstacle that Healthy Highrise designers need to overcome is the lack of regulatory demand for apartment ventilation as well as the perception by the highrise constructionindustry that change is both unecessary and too expensive.

Finally, the energy costs associated with inefficient fan operation and pre-heating of ventilation air are significant in many buildings. Recovery of heat from air exhausted from the building is not common.

Designers of ventilation systems should consider the following:

- Central vs. Individual Suite Systems
- Compartmentalization
- Filtering of Supply Air
- Reducing Heating Costs
- Ensuring Adequate AirFlow
- System Control
- Commissioning
- Operating and Maintenance

DESIGN CONSIDERATIONS

Mechanical ventilation systems must provide clean, tempered fresh air to the building occupants. Mechanical ventilation should also be the primary mechanism for exhausting excess humidity, odours, and pollutants from within suites and common areas of the building. When properly designed, installed and operated, mechanical ventilation systems can be the most efficient, secure and economically viable method of ensuring good IAQ in multi-unit residential buildings. They allow the occupant control over the quality of indoor air in the suite and should accommodate the operation of windows in suites.

Design of ventilation systems for high-rise residential buildings are governed by Part 6 of the 1999 National Building Code which requires that ventilation shall be provided by mechanical ventilation to each room or space in a building, at outdoor air rates no less than those specified by ASHRAE Standard 62 "Ventilation for Acceptable Indoor Air Quality".

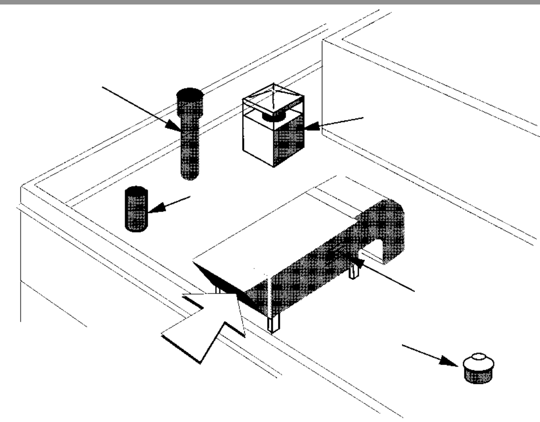
However, self-contained ventilation systems that serve only one dwelling unit have the option to be designed according to Part 9 of the National Building Code, which requires mechanical supply and exhaust systems and sets requirements for their design.

Part 9 has the following ventilation requirements:

- distribution of outdoor air to dwelling units by dedicated ventilation supply fans or by forced air system fans,
- principal exhaust fans,
- supplementary exhaust fans,
- quiet exhaust fans,
- preheat of ventilation air,
- supply and exhaust duct insulation,
- interlocked exhaust and supply systems.

Meeting the requirements of the CAN/CSA-F326-M91 Standard "Residential Mechanical Ventilation Systems" is also an option for complying with Part 9 heating season ventilation requirements. In meeting CAN/CSA-F326 requirements, designers must be aware of the

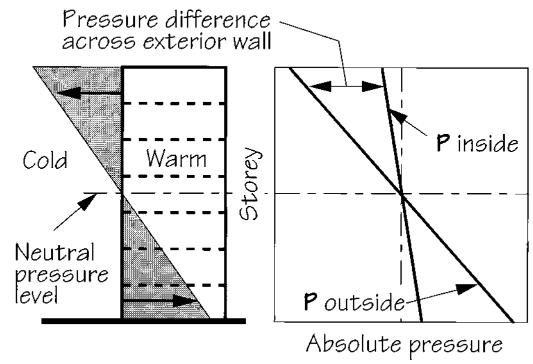
Sources of Contaminants for Make-up Air Units



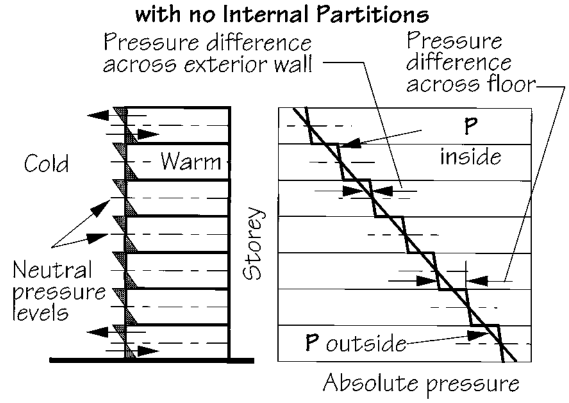
Consider wind effects caused by parapet walls and mechanical penthouses

Locate intake such that make-up air will not contain more contaminants than the "normal" exterior air

Stack Pressures in Winter



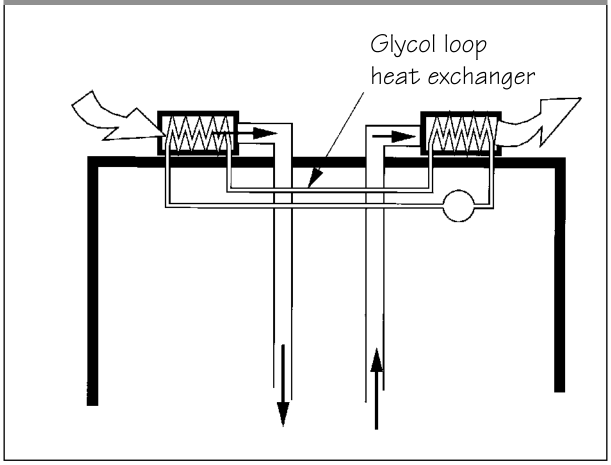
Simplified Stack Effect in Building with no Internal Partitions



Theoretical Stack Effect with Airtight Separation of Each Storey

Source: CBD 104, NRCC, 1968

Central Heat Recovery System



requirements to supply air directly to each room in the suite. This may entail separate ducting or dropped ceiling plenums within suites.

The ventilation flow rates dictated by ASHRAE Standard 62, Part 9 of the NBC, and F-326 can sometimes contradict one another. Therefore, designers must use experience to make rational design choices.

The implication of the ventilation system design on fire safety also must be carefully analysed (e.g. need to move air across fire separations- must be able to shut for smoke & fire control).

Central vs. Individual Suite Systems (Ensuite)

Central ventilation systems have the advantages of being a central point for control and maintenance, they have little space requirements in individual suites and can veray easily incorporate heat recovery in a single location. Because of the centralized control and maintenance, centralized systems are often preferred by rental owners.

Ensuite ventilation systems may be preferred by condominium owners because they are easier to meter on an individual suite basis, they allow greater individual control and separate maintenance responsibilities to individual suites. Ensuite ventilation systems allow greater compartmentalization of individual suites, and are easier to balance on an individual basis (reducing airflow through exterior walls and from other suites and common areas).

Compartmentalization

mproved ventilation for indoor air quality can best be achieved in high-rise residential buildings in the heating season with systems that directly supply ventilation air to occupants within their suites. And because effective performance of mechanical ventilation systems cannot be ensured unless internal air flows are controlled, the airtightness of the building envelope and separations between floors and suites must also be considered.

Designers might consider providing an airtight separation (compartmentalisation) of individual floors, thereby minimising the pressure difference across exterior walls. In essence, each floor would have a reduced pressure gradient design condition. Individual suites could also be compartmentalized/ isolated and ventilated by individual unit systems. This can be advantageous where individual control is wanted and metering is available. Better control of internal airflows can also reduce or eliminate many other problems such as odour migration and inadequate exhaust fan flow. The problem of noisy exhaust fans can be reduced by installing fans further away from occupants.

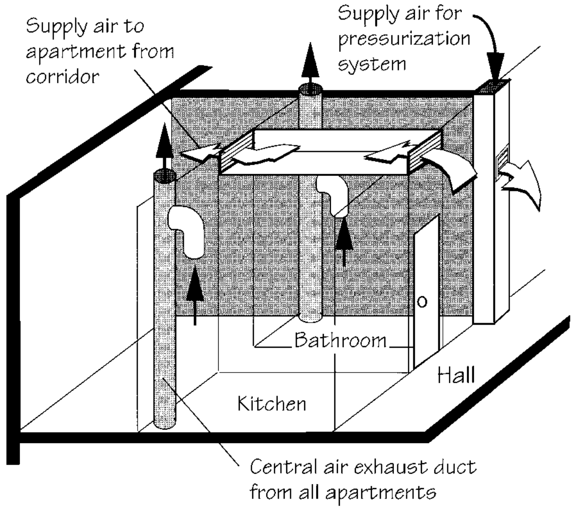
Filtering of Supply Air

To ensure the supply of clean air, filters should have a minimum efficiency of 50% ASHRAE average dust spot.

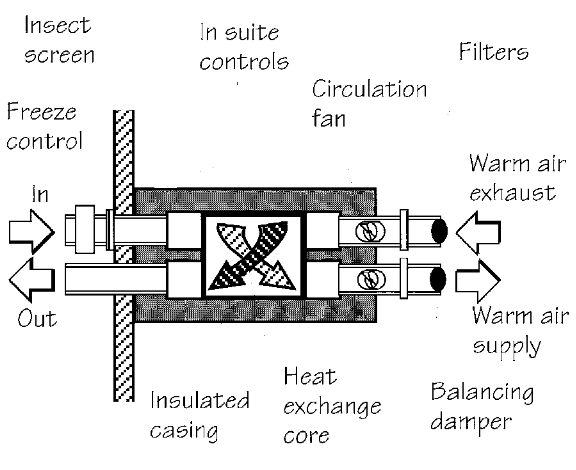
Reducing Heating Costs

Ventilation systems that provide well controlled rates of ventilation, alone or in conjunction with ventilation heat recovery, can significantly reduce energy consumption. Ventilation air must be pre-heated during winter in most parts of Canada. Otherwise occupants may experience drafts and discomfort, which could lead them to deactivate the system. Pre-heating of supply air can be accomplished by recovering heat from exhaust air streams. Central systems can be designed to transfer heat through glycol heat loops, while individual suites could employ air-to-air heat recovery ventilation units.

Central Supply and Exhaust



Individual Suite Balanced System



Supply air can also be pre-heated using solar energy. 'Solar walls' have been developed that can be mounted on south facing walls and pre-heat make-up air for ventilation systems.

Ensuring Adequate Airflow

Supplying fresh air to all rooms in the suite is the most desirable option from an indoor air quality perspective. Dropped ceilings may be required in hallways to house distribution ducts. Variable flow fans can provide both continuous ventilation rates and, as required, peak ventilation rates.

Supply air intakes located at the base of the building, with a capped top on the riser, will be less affected by stack pressures and will reduce back-drafting in supply air systems.

System Control

Humidity and/or CO″ sensor based controls can provide automatic boosting of the system from continuous to peak rates. Alternatively, manual controls in bathrooms and kitchen allow occupants to control ventilation based on their needs.

Commissioning

After installation of the system, air flows should be measured for compliance with the design ASHRAE Standard 62-99 for suites and common areas, and optionally 1995 NBC or CAN/CSA-F-326 requirements for individual suites. System balancing is essential for effective performance.

Operation and Maintenance

Systems should be designed with the skill level and time comitments of operators inmind. Operator training is essential. Maintenance manuals should be developed. Maintenance schedules must be followed to ensure that the system operates as intended. Regular maintenance of filters is required to prevent excessive pressure drops and loss of efficiency in the system.

Occupants should be educated on the operation of the system controls, and any maintenance responsibilities.

SOME SYSTEM OPTIONS

Central Supply and Exhaust

Air is supplied to rooms in the suite from a central supply system directly ducted from the central supply. Air is exhausted from each suite with a central exhaust system. Air should be supplied directly to all rooms without exhaust capacity.

Advantages

- Can provide a minimum continuous airflow to all suites.

- Reduces suite depressurisation and minimises envelope air leakage.
- Heat recovery to pre-heat supply air can be provided from a central location.
- Can be supplemented with individual suite exhaust or a booster fan in a central shaft.
- Single point of maintenance.
- No supply air intake required for each apartment.
- Building operators can control ventilation rates and ensure that the building is properly ventilated.
- Less space required in apartments than for ensuite systems.

Disadvantages
- Supply air transferred from corridors (if not directly ducted) may not meet fire safety requirements.
- Supply air inlets may be sealed by occupants to reduce noise and drafts (if not directly ducted).
- Increased building stack effect due to increased coupling of floors.
- Loss of occupant control.
- Larger common space committment(ie. mechanical rooms).
- Greater smoke, odour, noise and pest transfer is possible.

Individual Unit Exhaust - Central Supply Air

Dwelling units operate under continuous exhaust from individual dwelling unit systems. Fresh air is supplied through a central supply system - directly ducted from the central supply.

Advantages
- Can provide a minimum continuous airflow to all suites.
- Greater compartmentalisation of dwelling units.
- Exhaust rate controllable by occupants.
- No supply air intake required for each apartment.

Disadvantages
- No heat recovery of exhaust air possible.
- Difficult to balance.
- Loss of control by building owner
- Could pressurize the building and cause envelope problems.
- Supply air transferred from corridors (if not directly ducted) may not meet fire safety requirements.
- Supply air inlets may be sealed by occupants to reduce noise and drafts (if not directly ducted).

Individual Suite Balanced System

Air is supplied and exhausted from each dwelling unit with an individual unit heat recovery ventilation system (HRV), which recovers heat (or cold) from exhaust air flow to temper the incoming airflow.

Advantages
- Can provide a minimum continuous airflow to all suites.
- Heat recovery of exhaust air reduces energy consumption.
- Allows compartmentalisation of individual suite.
- Balanced air pressure in suites reduces airflow though exterior walls, vertical walls, vertical shafts, and from other suites and common areas.
- Easy to balance.
- Increased occupant control.
- Usage is billable to occupants.

Disadvantages
- Capital cost of HRV unit.
- Requires balancing.
- Requires separate system for corridors.
- Many points of maintenance.
- Large number of motors consuming energy.

RETROFIT OPPORTUNITIES

Ventilation systems in existing buildings often perform poorly compared to their original specifications. Retrofit opportunities to improve performance include:

1 Balancing airflows – Corridor pressurisation and central exhaust systems should be rebalanced to ensure that air supplies and exhaust rates are meeting their original specifications and are properly distributed throughout the building.

2 Installing ventilation supply to individual rooms –Central corridor pressurisation systems can be modified to supply ventilation air directly to individual suites. The only time that such a retrofit is possible is during major renovation.

3 HRV units can be installed in exterior walls of individual suites during renovation of each suite.

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.
- *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)
- *ASHRAE Standard 62*, American Society of Heating Refigerating and Air Conditioning Engineers Inc. (ASHRAE)
- *Model National Energy Code for Buildings*, National Research Council of Canada.
- CAN/CSA –F326-M91 *Residential Mechanical Systems*, Canadian Standards Association.

CASE STUDY

Window Retrofit Improves Air Quality and Soundproofing

HELSINKI, FINLAND

In downtown Helsinki, a 7-storey (81 unit) apartment building was retrofit with improved levels of occupant comfort. The 1960 building, is located on a busy street in a high-density neighbourhood. This project's goal was to improve ventilation and to demonstrate a new fresh air window with high sound insulation properties.

All 110 occupants were surveyed before and after the retrofit. Reported indoor climate problems were draughts, traffic noise and dust from the street. The mechanical ventilation system was unbalanced. Low exhaust was due to dirty exhaust vents and did lack of specific outdoor air inlets. All suites had exhaust air registers in kitchens and bathrooms.

Before the renovation, moisture damage and mold was visible in many suites. Nearly half of the suites had some form of moisture damage, mostly in bathrooms. Almost half of the exhaust duct inspected had no air flow due to dirt build-up. At full fan speed, the average air intake was 8.4 l/s and 7 l/s in kitchens and bathrooms, respectively. The sound insulation of the old double-pane windows was 26-28 dB, which is far below the Canadian standard of 55 dB. The traffic noise level inside suites was 39-42 dB, 14% greater than current Finnish guidelines.

THE INNOVATION: WINDOW RETROFIT

New windows installed in suites facing onto streets consisted of two parts, a triple-pane window and a separate fresh air shutter for air intake and for access to an air filter, located at the bottom of the shutter. Air entered at the bottom of the window and was filtered, before rising through a rectangular channel (2.5 cm by 20 cm) and entering the suite through a radial diffuser. The thickness of the glass from outside to inside was 8 mm, 6mm and 6mm. The window was designed by architect Alpo Halme.

This system allowed an air intake rate of 7 l/s while not exceeding the Finnish National Building Code maximum air velocity in occupied areas. The air change rate in all suites was at least 0.5 per hour, even at lower kitchen and bathroom exhaust fan settings. Average exhaust air flow at full fan speeds improved by 25%, to 12 l/s and 9 l/s for kitchens and bathrooms, respectively. Sound insulation also improved. Measurements showed that interior decibel levels dropped due to the higher sound insulation value of the new windows. The sound insulation level increased by 30%. Suites not facing onto streets had similar windows installed. These windows required less sound insulation and air filtration efficiencies, however.

Occupant Survey: Reported Indoor Air Related Problems Before and After a Window Retrofit

Problem	Before Retrofit	After Retrofit	Improvement
Draught	61.7%	22.4%	39.3%
Traffic Noise	53.2%	17.2%	36%
Stale Air	31.9%	10.3%	21.6%
Insufficient Ventilation (winter)	34.0%	13.8%	20.2%
Insufficient Ventilation (winter)	42.6%	24.1%	18.5%
Dust on Surfaces	53.2%	39.7%	13.5%
Unpleasant Odour	23.4%	13.8%	9.6%

Results of the occupant surveys showed great improvements to perceived draughtiness and traffic noise inside suites. There were 39% fewer complaints regarding draughts and 36% fewer complaints of traffic noise. The table at right summarizes the change in perceived problems by occupants before and after the window retrofit.

The window retrofit showed that it was possible to install a window that allowed outdoor air intake without draughts while providing adequate sound isulation and air filtration.

Project Info

Location: Helsinki, Finland

Project Participants: Helsinki University of Technology
Alpo Halme Architect

Project Support: Ministry of Environment

Completion Date: 1998

Further Information: Laboratory of Heating, Ventilating and Air-Conditioning Faculty of Mechanical Engineering
Helsinki University of Technology
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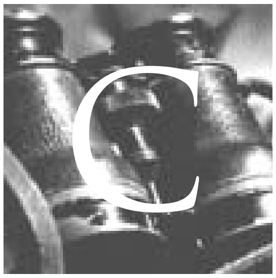

CASE STUDY

Finnish Guidelines Prove a Useful Tool for Better Indoor Air Quality

THE PUIJONKARTANO

In Finland, a 7-storey apartment building was constructed in 1997 using guidelines established by the Finnish Classification of Indoor Climate, Construction and Finishing Materials (CICCFM). Though not an official code, this 3-part guide was prepared to assist clients, designers, builders and manufacturers to achieve good indoor air quality in buildings. It includes (1) target and design values for thermal conditions, odour intensity, noise levels, ventilation and indoor air pollution, (2) principles and procedures for construction and (3) limit values and emission rates for building and finishing materials. A second, identical building was constructed using standard construction methods and specifications. Indoor air parameters were measured in one apartment on each floor of both the two buildings before occupants moved in and after a 5-month occupancy. The comparison concluded that good indoor air quality can be achieved in apartment buildings through careful design, choice of proper materials and equipment and high-quality construction.

THE INNOVATION: CAREFUL DESIGN AND SPECIFICATIONS

The case-study building uses a mechanical supply and exhaust system. Supply air is filtered using fiberglass. A heat recovery unit was installed and ventilation air is exchanged 1.7 times every hour. Finishing materials were chosen according the CICCFM specifications. The ventilation system was also kept at a high capacity for one week after building completion, before occupants moved into the building.

Measurements were taken for various emissions, including total volatile organic compounds (TVOC), carbon dioxide (CO_2), ammonia, total suspended particles, formaldehyde and carbon monoxide (CO). The results at left summarize air quality testing in terms of the percentage of reduction of the contaminant in the case-study building versus the control building.

The most dramatic difference between the two buildings was the emission rate of TVOC, which was initially 77% lower in the case-study building. After building ventilation, TVOC levels were 90% lower in the case-study building and 79 % lower after 5-month occupancy. The lower TVOC levels were most likely the result of lower-emitting building and finishing materials, a higher ventilation rate and the one week ventilation period before occupancy. The ventilation period reduced aromatic and aliphatic hydrocarbons from paints, glues, adhesives and from materials like carpets, wallpaper and gypsum.

The strictest CICCFM target values for CO_2, formaldehyde and total suspended particles were achieved before occupancy. CO and ammonia met the target levels after 5-month occupancy. A lower CO_2 level in the case-study building was the result of a higher ventilation rate. A lower ammonia level was achieved by carefully controlling the drying of concrete before the installation of finishing

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Canada

Contaminant	Reduction
TVOC[1]	79%
Ammonia[1]	69%
Carbon dioxide[1]	49%
Formaldehyde[2]	44%
Total Suspended Particles[1]	25%

[1] - after 5-month occupancy
[2] - before occupancy

materials. Formaldehyde levels were 44% lower in the case-study building when tested before occupancy due to careful selection of building materials.

Project Info

Location:	Kuopio, Finland
Project Participants:	University of Kuopio Keuhkovammaliitto, Kaprakka Kuopio Regional Institute of Occupational Health
Project Support:	Ministry of Environment Ministry of Social Affairs and Health City of Kuopio The Academy of Finland Graduate School for Building Physics Sato-Rakennuttajat Oy
Completion Date:	1997
Further Information:	"Usefulness of the Finnish classification of indoor climate, construction and finishing materials: comparison of indoor climate between two new blocks of flats in Finland" in Atmospheric Environment 35 (2001) 305-313 by Marja Tuomainen et al.

ENHANCING ENVIRONMENTAL PERFORMANCE

In This Section

Site Planning
- preservation and protection of natural features
- building location and footprint
- building orientation

Materials Selection
- source / quality of materials
- embodied energy
- quantities of materials
- impact on occupant health
- impact on natural ecosystems
- materials selection guidelines

Solid Waste
- building construction
- building operation
- building demolition
- waste management plans

Water
- domestic indoor water uses
- HVAC systems
- exterior water use
- on-site water treatment

Landscape Practices
- water-efficient
- energy-efficient
- stormwater management

Occupant Comfort - Noise
- verification
- doors
- windows
- air borne noise
- impact noise
- mechanical equipment rooms
- plumbing system
- installation

Regional Differences

Case Studies

Concerns for the susceptibility of our environment are increasing. The deterioration of the ozone layer and air quality in urban areas, the depletion of fresh water supplies and the degradation of water courses, and the loss of natural habitats all represent societal problems that need to be addressed.

Residential development has a major impact on the environment at both local and global scales. A new building can destroy local natural ecosystems, and can impact negatively on adjacent development. Both the construction and operation of residential buildings consume vast quantities of energy, materials, water, and land. The waste emissions and pollution associated with buildings are also significant. In order to sustain the quality of the environment and healthy lifestyles, it is crucial that residential development use resources more effectively and more efficiently, while preserving the integrity of the local ecosystem. In response to these needs, the design and construction industry has begun to make advances.

In most cases, environmentally responsive design will not significantly increase design or construction costs. For example, orienting a building to optimise solar gains, or specifying low flow water fixtures, can result in operating cost savings. At the same time, there are many precedents of residential developments where an environmentally responsive design approach resulted in greatly reduced infrastructure costs. Indeed, when a lifecycle assessment approach is used, the benefits of 'green' design far outweigh the costs.

The following section provides an overview of possible approaches for enhancing the environmental performance of high-rise residential buildings. It discusses this issue from the point of view of local ecological impacts, resource use and attendant waste emissions, and indoor occupant health.

SITE PLANNING

Related Topics

Wetting of Building Envelopes
Space Heating and Air Conditioning
Mechanical Ventilation
Solid Waste
Landscape Practices
Flexibility

THE ISSUES

A building has a permanent environmental impact on its site, both in terms of changes to the surrounding ecosystem, and its relationship to the local community. Initial site planning is key to the overall environmental performance of the building. It has ramifications on all other aspects of design. Through careful attention during early stages of design, the building designer can anticipate negative ecological impacts, improve the quality of the development, and enhance the sustainability of the neighbourhood. The basic considerations include:

- Preservation and Protection of Natural Features
- Building Location and Footprint
- Building Orientation

DESIGN CONSIDERATIONS

Preservation and Protection of Natural Features

The site plan should be premised upon preserving, protecting, and enhancing such natural features as site contours, stream channels, hydrological flows, existing vegetation, scenic views, and wildlife habitats. These features all play integral roles in the proper functioning of the ecosystem as a whole, and can contribute significantly to proper building functioning.

Restrictions on development of environmentally-sensitive or important productive lands are crucial. Agricultural, forest renewal and hazardous lands, or lands that might result in extensive environmental damage, should have limited development. For example, steep slopes and hillsides, flood plains, and wetlands are all examples of areas where development should be restricted and / or regulated.

Building Location and Footprint

The construction of high-rise buildings can affect the local microclimate, modifying wind and sun patterns in the area, and shading other buildings and ecosystems. The building should be sited to create desirable summer and winter microclimates at the pedestrian level.

The location of a building on a site can result in positive or negative environmental impacts. Consideration should be given to the impact of the building on views, how much of the site will be disturbed both during construction and operation, soil capabilities, linkages to transportation networks, existing buildings on site, changes to the microclimate caused by altering the contours of the land, and so on.

In order to minimise site disturbance for construction, buildings and access roads can be aligned to follow the length of existing contours.

The building’s impact upon local solar access is an important consideration. Buildings should be located to minimise the loss of solar access to surrounding buildings and publicly accessible, open space areas. This is an important consideration for colder climates in particular.

Ideally, high-density development should have good access to services and amenities, maximising the potential for pedestrian travel and minimising the need for the automobile. Easy access to public transit, stores, health services, schools, and recreational facilities all provide for a more sustainable approach to development.

Opportunities for mixed uses at the lower levels of the building can reduce infrastructure costs and provide for a livelier community aspect in the building. Examples of mixed uses include day-care space for children and the elderly, as well as the more typical small-scale retail, professional and commercial facilities.

Design of site features such as outdoor sitting areas, playgrounds and allotment gardens provide an opportunity for building residents to enjoy the outdoors and socialise around a common interest.

There are many other opportunities to enhance the relationship of the building to the neighbourhood. These include orienting the building to pedestrian traffic, massing and siting the building to relate to the scale of surrounding structures, providing an entrance design that is pedestrian friendly, and minimising the use of large quantities of pavement.

Building Orientation

A building's orientation has enormous impacts on the ability to optimize all opportunities for environmentally-responsive design strategies. For example, natural daylighting, heating, and ventilation strategies are all linked to the building's proper orientation.

A site's latitude determines the sun's azimuth at any given time of day and year. Simple calculations will determine the path of the sun and a building's orientation should be determined to take advantage of this information. The effectiveness of passive and active solar systems will be enhanced with appropriate building orientation and maximum access to sunlight (SSE to SSW 5% to 15%).

Consideration should be given to the minimisation of solar shadows. The calculation of site shading can avoid the creation of on-site solar voids and cold-air drainage dams that collect pools of cold air. The shading of adjacent buildings and lots should also be avoided. This is particularly important in temperate and cold climates.

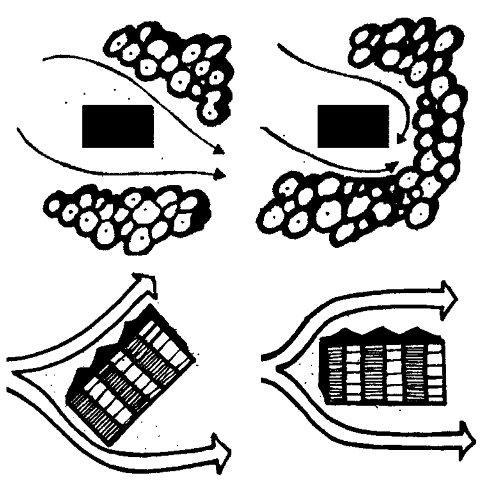
The building should be orientated to consider existing airflow patterns and their cooling effect in both summer and winter. Consideration should also be given to the building's effect upon local wind patterns and snow accumulation, avoiding adverse effects upon adjacent buildings or public open spaces.

A building should also be oriented so as to maximize the safety, ease of access and protection from the elements of its entranceway. The use of overhead structures near entranceways, for example, can provide pedestrian protection from cold downdrafts.

RETROFIT OPPORTUNITIES

While there are few changes that can be made to a building's location or orientation through retrofits, there do exist some opportunities for improving the environmental performance of a building through site alterations.

At the site level, the most readily available and least costly opportunities are through modifications to the surrounding microclimate. In many cases, such retrofits can improve the energy performance of the building at the same time as improving the relationship of the building to its natural context. For example, altering paving materials (from asphalt to pervious pavers) can lead to reductions in surrounding micro-climate temperatures that



Air infiltration is affected by the building's orientation to prevailing winds as well as the presence of dense vegetation.

in turn reduce the cooling loads on the building while also addressing stormwater run-off issues. Another example is to add landscaping interventions that enhance the natural features of the site while also improving the building's energy performance. These can include such things as adding deciduous plants on the south and west sides of a building to allow for summer cooling and winter solar access.

Sources of Information

- *Sun, Wind, and Light: Architectural Design Strategies*, Brown, G.Z., John Wiley & Sons, U.S.A., 1985.

- *Sunlighting as Formgiver for Architecture*, Lam, William M.C., Van Nostrand Reinhold Company, U.S.A., 1986.

- *Santa Monica Green Building Design & Construction Guidelines*, The Sheltair Group et. al, 1999.

- *Time-Saver Standards for Landscape Architecture*, Harris C. & N. Dines, McGraw-Hill, U.S.A., 1998.

- *Energy and Water Efficiency in Multi- Unit Residential Buildings*, Technical Manual, CMHC, 2000.

- *Tap The Sun: Passive Solar Techniques and Home Designs*, CMHC, 1998.

- *The Climatic Dwelling*, E. O'Cofaigh, J.A. Olley, and J.O. Lewis. Energy Research Group, School of Architecture, University College of Dublin, Republic of Ireland, James & James, 1996.

MATERIALS SELECTION

Related Topics

Parking Garages
Source Reduction
Solid Waste
Landscape Practices
Flexibility

THE ISSUES

The materials used for the construction, operation, maintenance and renovation of buildings represent enormous quantities of resources. As well, the extraction, transformation, use and disposal of raw materials cause equally significant impacts on the environment. Habitat destruction, resource depletion, air pollution, and solid waste represent some of the environmental costs associated with the flow of construction materials. For this reason, design professionals now often include environmental considerations into the materials selection process. In particular, life-cycle assessment / analysis of construction materials and design guidelines that specify the use of 'green' materials are available. The key considerations involved in the selection of materials include:

- Source / quality of materials
- Embodied energy
- Quantities of materials
- Impact on occupant health
- Impact on natural ecosystems
- Materials selection guidelines

DESIGN CONSIDERATIONS

Source / Quality of Materials
Many materials come from sources which are considered non-renewable or which involve more severe negative environmental impacts than others. Tropical hardwoods are considered a scarce resource, not just because they represent an endangered species, but also because the acquisition process causes dire ramifications on biodiversity. The selection of materials should involve consideration of the source in order to ensure that a non-renewable material is not being used. For wood products, third-party forest certification is the best way to guarantee the suitability of the source.

The source of materials also refers to whether materials are virgin or whether they are salvaged. Using salvaged materials and materials with recycled content reduces the extraction of raw resources. Assemblies that allow easy extraction of the material for recycling when the building is eventually replaced also result in reduced environmental impact.

It is also necessary to consider the quality of the materials. Lower quality, less durable materials will require frequent replacement—meaning that more resources will be used without adding any value to the building. While lower quality materials may cost less at the building's inception, both the economic and environmental cost will be much higher over the lifetime of the building. Durable materials with a long service life typically are those that are low-maintenance and that result in lower operation costs. Hard flooring, for example, has several times the service life of vinyl flooring or carpets, and reduces both waste and cleaning requirements.

Embodied Energy

Embodied energy is the term used to describe the energy input invested in a material during extraction, manufacturing, transportation, and installation. Through choice of materials, the designer can greatly influence the embodied energy invested in the building as well as the energy required to operate the facility. The goal is not to minimize embodied energy per se, but to consider its significant contribution to total life-cycle energy associated with the building. As a case in point, processing of recycled aluminum requires only 5% of the energy necessary to produce aluminum from bauxite.

Because only 7% to 10% of the embodied energy in buildings is the result of the on-site construction process, it is crucial to expand embodied energy calculations to include the entire life-cycle of the building and its attendant material requirements. For example, if the construction of a new building involves the demolition of an existing on-site building, the initial embodied energy calculations should include materials removed through demolition. Reducing the embodied energy of a building can be achieved through:

- increasing the useful life of buildings and their components,
- reducing the energy intensity of building materials (such as fly-ash substitution in concrete),
- reducing the amount of material in a building,
- reducing construction waste,
- using advanced framing techniques,
- increasing the amount of recycled material in a building,
- using more durable materials,
- using local rather than imported products.

Quantities of Materials

Very large quantities of materials are used to construct and maintain buildings. The failure to optimize designs results in an excessive amount of materials being used. Opportunities exist to eliminate oversized and decorative materials and still achieve appropriate aesthetic appeal. Finishes with short life spans, such as carpeting, account for a large percentage of lifecycle costs.

Waste also results from non-standard dimensions in the design. Off-cuts from studs and wall panels are examples. By using the common dimensions of materials such waste can be reduced. Use of engineered wood products, such as stair stringers, can also help to minimize material quantities.

Initial and Lifecycle Embodied Energy

Material	Initial Embodied Energy (%)	Lifecycle Embodied Energy (%)
Concrete	45%	28%
Finishes	13%	23%
Mechanical	13%	13%
Door & Windows	5.8%	8%
Metals	4.4%	5%
Site Work	4.3%	5%
Thermal & Moisture Protection	4.2%	4%
Masonry	3.9%	5%
Electrical	3.4%	4%
Specialities	1.3%	2%
Wood & Plastic	1.0%	2%
General	0.3%	0%

Assume: Canadian concrete structure, four storey multi-unit residential building without underground parking.

Impact on Occupant Health

Many materials used in constructing and operating buildings have negative impacts on the quality of the indoor air, and can result in health problems for the occupants. Indoor air pollution can be partially attributed to chemicals emitted by materials, to materials that trap dust and odours, or that support the growth of bacteria and molds. Examples include products containing formaldehyde glue, new carpets, various flooring materials, paints and sealants, and so on. Examples of materials that are ‘healthy’ include low-VOC paints and adhesives, low emission carpets (often made of natural fibres) and hard non-porous materials (see Indoor Air Quality in this document).

Impact on Natural Ecosystems

Many industries today are adopting a life-cycle product stewardship model as a way of incorporating environmental concerns into all stages of the product’s life. For building design, this means comparing the environmental impact of materials resulting from: extraction and processing, manufacturing, transportation and packaging, installation, operation, maintenance and replacement, and eventual disposal or recycling potential. Certification programs, such as for wood from sustainably managed forests, represent a key strategy for ensuring limited impact on natural ecosystems.

Materials Selection Guidelines

At the design concept stage, it is helpful to develop comprehensive design guidelines that include selection of ‘green’ materials. The following guidelines are examples of practices that can be included and that could improve the design and materials specification process.

RETROFIT OPPORTUNITIES

While there are few changes that can be made to a building's location or orientation through retrofits, there do exist some opportunities for improving the environmental performance of a building through site alterations.

At the site level, the most readily available and least costly opportunities are through modifications to the surrounding microclimate. In many cases, such retrofits can improve the energy performance of the building at the same time as improving the relationship of the building to its natural context. For example, altering paving materials (from asphalt to pervious pavers) can lead to reductions in surrounding micro-climate temperatures that in turn reduce the cooling loads on the building while also addressing stormwater run-off issues. Another example is to add landscaping interventions that enhance the natural features of the site while also improving the building's energy performance. These can include such things as adding deciduous plants on the south and west sides of a building to allow for summer cooling and winter solar access.

Examples of Green Building Materials

Foundations

- ABS drain tile with recycled content
- Pier foundation systems
- Concrete with fly-ash content

Walls

- Insulation with high recycled content
- CFC and HCFC-free insulations
- Cellulose insulation
- Drywall with high recycled content
- Steel / aluminium/ vinyl with recycled content

Roofing

- Recycled rubber roof deck
- CFC and HCFC-free rigid insulations
- 'Green' Roofs

Interior Finishes

- Zero- and Low-VOC paints
- Zero- and Low-VOC caulks and adhesives
- Bio-based natural materials (cork, linoleum, wool, sisal, etc.)

Landscaping

- Rubber flooring from recycled tires
- Chipped wood waste for flower beds
- Crushed concrete as aggregate for road sub-base

Materials Selection

1. Specify recycled products and attendant strategies.
2. Specify reuse of salvaged building materials.
3. Design with panel, pre-cut and engineered constructio products.
4. Specify durable exterior and interior finishes.
5. Specify wood from sustainably-managed sources.
6. Use low-emissions finishes and interior materials.

source: Santa Monica Green Building Design & Construction Guidelines, 1999

Sources of Information

- *Environmental Building News: @* http://www.buildinggreen.com (especially *"Building Materials: What Makes A Product Green?"* from EBN Volume 9, No.1, January 2000)
- *Environmental Resource Guide*, The American Institute of Architects, John Wiley & Sons, 1996.
- *Santa Monica Green Building Design & Construction Guidelines*, The Sheltair Group et.al, 1999.
- *Building Materials for the Environmentally Hypersensitive*, CMHC, 1995.

SOLID WASTE

Related Topics

Site Planning
Materials Selection

THE ISSUES

In 1998, an estimated 4.6 million tonnes of solid waste was generated from construction and demolition sources in Canada. This total represents 157 kilograms for each Canadian. The generation of solid waste results in pressure on landfill space, and the contamination of soils and water. It can also indicate that a material object has been removed from the productive cycle well before the end of its useful life.

In terms of residential buildings, solid waste is created during both the construction and operation of the building. Researchers estimate that for every $1 billion spent on construction, 40,000 tonnes of waste are produced. Currently, 16% of the total volume of Canada's landfills can be attributed to residential construction waste[1]. The amount of solid waste generated from day-to-day operations varies, but is equally significant. For these reasons, it is crucial that the generation of solid waste during construction and daily operations be reduced. Along with these environmental issues, rising disposal costs and bans on disposal of some construction materials require that the construction industry integrates waste management planning into its projects.

Key considerations to address with respect to solid waste include:

- Building construction
- Building operation
- Building demolition
- Waste management plans

[1] "Challenge: Reducing Residential Construction Waste", CMHC brochure

DESIGN CONSIDERATIONS

Building Construction

Construction waste makes up a significant proportion of the total waste stream: residential construction wastes are estimated to represent approximately 16% of wastes taken to landfill.[1] As much as 1 1/4 tonnes of new products brought to the site are wasted in the construction of an average house. Both the economic and environmental costs of disposing of this waste are enormous. However, construction waste can be cut by as much as 85%, and disposal costs significantly reduced by implementing plans which are based on the 4 R's of waste management.

Building Operation

The solid waste that is generated during the operation of residential buildings is typically comprised of consumer products and organic waste from food preparation and landscaping. About half of the solid waste stream from residences consists of packaging materials; approximately 30% of organic materials, and the remaining 20% is made up of other paper products, textiles and small amounts of old appliances and household hazardous products.[2] Through recycling and composting strategies, up to 80% of this waste stream could be reduced. If appropriate dedicated facilities for composting and for recycling storage / handling / pickup are integrated into a building's design, residents will have the opportunity to achieve such reductions..

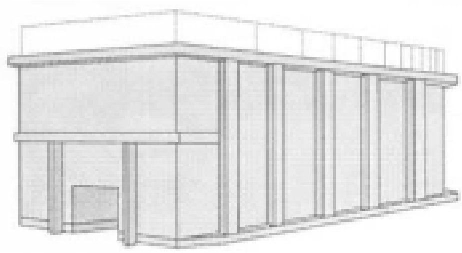
Construction and Demolition Waste

Province	Construction and Demolition Waste (tonnes)	Total Waste[1] (tonnes)	% of Total
British Columbia	408,211	2,458,484	16.6%
Alberta	611,493	2,527,817	24.2%
Ontario	733,507	6,988,157	10.5%
Quebec	566,194	5,537,465	10.2%

[1] Includes Residential, Industrial, commercial and institutional, Construction and demolition, Other.
Source: Waste Management Industry Survey 1998, Statistics Canada 16F0023XIE.

Percent by Volume of Residential Construction Waste

25% Dimensional Lumber
15% Manufactured Wood
12% Drywall
10% Masonry and Tile
10% OCC (Cardboard)
6% Asphalt
5% Dimensional Lumber
5% Other Wastes
4% Metal Wastes
4% Plastic and Foam
4% Other Packaging



Demolition materials separated for recycling and reuse at the Spencer Creek Village Project in Dundas, Ont. @ http://www.cmhc-schl.gc.ca/rd-dr/en/hr-trs/e_dunda1.htm

Building Demolition

The waste caused by demolition represents one of the largest contributors to the waste stream. The economic costs associated with disposing of this waste are also significant. It is estimated that approximately five to eight percent of the total job costs are allocated to disposal. By managing demolition responsibly, however, significant quantities of demolition waste can be diverted from disposal. Case studies have shown that up to 90% of waste generated in demolition can be diverted cost-effectively.[3] Through dismantling rather than demolishing a building, for example, such savings can be achieved from both cost and environmental perspectives.

Waste Management Plans

Establishing waste management plans can reduce the costs associated with disposal, and can improve demolition and construction practices. Waste management plans are based on reviewing, reducing, reusing and recycling.

Review

- Perform a waste audit, tracking amount and type of average construction waste,
- Review conventional practices which contribute to excessive waste generation and develop alternative procedures,
- Identify disposal costs and restrictions.

Reduce

- Implement purchasing options that minimize packaging and product waste (i.e. bulk purchase of sealants, reusable packaging containers, no packaging left on site by suppliers, etc.),
- Avoid damage and deterioration of construction materials by proper on-site handling practices,
- Select equipment and materials which allow for repair of parts and components rather than requiring replacement.

Reuse

- Conduct pre-project waste inventory to optimize re-use opportunities,
- Retain existing buildings or materials,
- Reuse materials on site (i.e. crushed masonry for driveway fill, drywall scraps in interior partitions, etc.),
- Sell or give away demolition materials.

Recycle

- Identify markets for recycle materials,
- Separate materials on site as they are produced for recycling purposes,
- Use recycled content and recyclable construction materials where possible.

[1] Making a Molehill Out of a Mountain, CMHC, p.5
[2] Sustainable Urban Development Guidelines for Southeast False Creek, The Sheltair Group, April 1998, p.63
[3] Provincial Demolition Material Diversion Strategy Discussion Paper, BC Environment, Spring 1999

RETROFIT OPPORTUNITIES

The focus of retrofit opportunities in terms of solid waste is on ensuring the most appropriate facilities for collecting, storing and handling waste for recycling and composting. Although the best opportunities for providing dedicated waste management spaces exist during initial design and construction, the conversion of interior and exterior spaces to perform waste handling functions is possible. While it is unlikely that a building will be retrofitted with recycling collection chutes or shafts, it is possible that spaces can be modified to permit the separation, collection and storage of materials for recycling and / or composting. These spaces should be large enough to accommodate a significant diversion rate, and should be easily accessible to occupants and to custodial staff.

Sources of Information

- *Making a Molehill Out of A Mountain*, CMHC, 1991.
- *Challenge: Reducing Residential Construction Waste*, CMHC brochure.
- *Santa Monica Green Building Design & Construction Guidelines*, The Sheltair Group et.al, 1999
- *Green Building Challenge (GBC)'98 Assessment Manual: Multi-Unit Residential Buildings*, Cole, Raymond & Larsson, Nils, Buildings Group, Natural Resources Canada,1998. @ http://www.greenbuilding.ca
- *Sustainable Urban Development Guidelines for Southeast False Creek*, The Sheltair Group Inc., 1998.

WATER

Related Topics

Low Slope Roofing Systems
Site Planning
Landscape Practices

THE ISSUES

Increasing residential demand for water is placing significant pressure on water supply, delivery, and treatment infrastructure. It is an issue that results not only in negative environmental impact, but that also is significant from health and economic perspectives. From a resource point of view, the issue is one of declining supplies, as manifested in lower lake, river, groundwater and aquifer levels. From an ecological point of view, it is an issue of degraded fish and riparian habitats. From a health point of view, it is an issue of declining water quality. From an economic point of view, it is an issue of the need for municipalities to keep pace with the required costs for upgrading and replacing infrastructure.

At the Municipal Level

Many Canadian municipalities are being forced to revise their water supply policies. Shortages of water at peak demand period, and the expensive infrastructure costs associated with new supply and treatment facilities require new demand management strategies. For many municipalities, water efficiency and related demand management measures are an attractive, cost-effective alternative to more expensive sources of new supply.

At the Building Level

To the building occupant, water and sewage costs are consuming a larger and larger portion of their housing dollar. Current consumption of water in Canadian high-rises averages 275 litres/person/day.

Water efficiency measures involving plumbing systems and fixtures have demonstrated that reducing per capita consumption of water by 40 to 50% is both possible and practical. The Conservation Co-op in Ottawa, for example, has achieved consumption levels of 150 litres/person/day, a 45% reduction from the Canadian average.

Current landscape watering practices can double the rate of water use, compared with winter levels. Not surprisingly, exterior water use is responsible for summer municipal peak demands (see Landscape Practices in this section).

The key considerations included in water consumption and conservation include:

- Domestic indoor water uses (toilet flushing, bathing, washing cleaning and drinking)
- HVAC components (cooling towers)
- External water use
- On-site water treatment
- Stormwater retention (see Landscape Practices)

DESIGN CONSIDERATIONS

Domestic Indoor Water Use

Toilets

Conventional toilets often use in excess of 20 litres per flush and consume 40%-45% of total indoor household water. Current off-the-shelf technology is demonstrating that ultra-low-volume (ULV) toilets can use between 2 to 6 litres per flush and still generate the same consumer acceptance.

The incidence of double flushing and plunging to unclog gravity ULV units is higher than for pressurized tank ULVs. However, pressurized units may be noisier than gravity units and have a higher installation cost. ULV toilets should be checked after installation to ensure that 6 litres/flush is not being exceeded.

Composting toilets are an alternative method that eliminate water consumption for toilets altogether. These use the natural processes of decomposition and evaporation to recycle human waste. Ninety percent of human waste is water content and is evaporated, while the remaining amount is converted into a fertiliser soil. This option may only be applicable to new buildings, due to the cost of a retrofit.

Also, CSA certified dual flush toilets have recently become available in Canada. These typically offer the option of a 3 or 6 litre flush.

Showerheads and Faucets

Domestic showerheads and faucets are the second and third largest water-using fixtures. Showerheads account for 17%-22% and faucets account for 10%-15% of total indoor use.

Current ULV showerheads and faucets can reduce flow rates to as low as 2-5 liters per minute (L/m), compared to conventional 10-20 L/m fixtures. It is important for designers to match flows with needs, however. For example, while a flow rate of 2 L/m is sufficient to deal with personal hygiene (hand washing, tooth-brushing, shaving), flow rates of 6-9 L/m are required in the kitchen.

With low flow shower and faucet fixtures, energy savings (from less hot water heating) and water cost savings would be about 45% combined or as much as $100/suite[1].

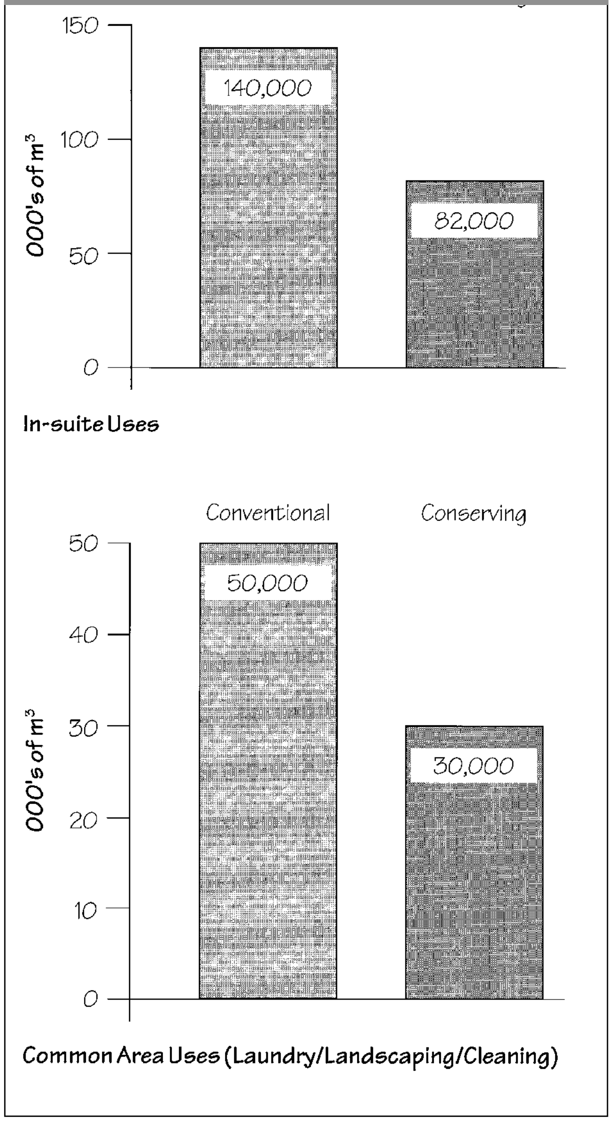
[1] assumes a typical 3-person suite at 135 m^3/year.

Washing Machines

Laundry and dishwashing accounts for 6%-10% of typical indoor water use. Designers should specify clothes washers and dishwashers which allow for variable time or load settings and which also have a good EnerGuide rating. Horizontal-axis (H-axis) front-loading (and more recently, top loading) washers tumble clothes clean using up to 66% less water. They also spin clothes drier, giving energy savings at the drying stage as well.

A typical common area washing machine might use 675 m^3 of water per year. An H-axis model will use a minimum 40% less. The savings would be $275/year (at $1.00/$m^3$). Over time, this would offset the additional purchase cost (about 1/3 more than conventional models).[2]

Annual Water Use in a 720-Unit High-rise



Leakage

Repairing leaks is an easy and cost-effective method of saving water. Immediate savings from both resource and economic perspectives are reaped. Toilet replacement may eliminate undetected leakages, commonly at the flapper valve on older toilets.

HVAC Systems

The principal water use associated with HVAC components in a high-rise building relates to evaporative losses from cooling towers. It should be possible to reduce evaporative losses to less than 5% through better design. Opportunities to reuse water for make-up purposes should be explored, rather than using potable supplies.

Exterior Water Use

Outdoor water consumption is a major concern to water authorities. Peak monthly demand for water occurs during late summer when municipal reservoirs are at their lowest levels. Most municipalities that impose watering restrictions do so during summer months when outdoor water use substantially increases overall consumption. There are many conservation practices that can reduce outdoor water consumption. Some of the most common approaches are discussed later in this section, in Landscape Practices.

On-Site Water Treatment

Centralised wastewater treatment is the status quo for most municipalities. These sewage collection and treatment networks represent extensive infrastructure with large energy requirements. Canadian municipalities use substantial amounts of energy in the operation of water and wastewater treatment facilities. The total amount of energy used is approximately equal to the energy required to operate all municipally-owned buildings and facilities. Of the total energy required for these operations, wastewater treatment plants account for approximately half, or 2200 GWh per year[3].

Municipalities use water conservation policies to reduce peak water demand, defer the upgrading of facilities and to ensure adequate supplies of water. These also have the additional benefit of reducing energy consumption at water and wastewater plants.

One strategy to reduce water consumption is to use on-site infrastructure to treat wastewater and reuse it for non-consumptive purposes. On-site treatment systems offer an alternative to the conventional centralised approach. Essentially the on-site systems provide a modularised and low cost system for treatment in close proximity to the buildings. The on-site systems can be built incrementally, which reduces the need for large capital expenditures. Moreover, since key components of the infrastructure may be located within each private development, municipal expenditures can be further reduced. On-site operations provide primary and secondary treatment that produces water that is colourless, odourless and suitable for many re-uses within the vicinity. Also, the treatment facility can be designed for multipurpose use, giving added value to nearby residents. For example, a secondary function of a solar aquatic liquid waste treatment system is a greenhouse.

[1] Energy and Water Efficiency in Multi-Unit Residential Buildings, CMHC, p.7-4.
[2] Energy and Water Efficiency in Multi-Unit Residential Buildings, CMHC, p.7-3.
[3] Municipalities Table Options Paper 1999, Natural Resources Canada, p.131

RETROFIT OPPORTUNITIES

At some point in the life of a building, water fixtures require replacement. Water system retrofits offer the opportunity for consumption cost savings that will offset retrofit costs over relatively short time periods.

Toilets

Old fixture replacement will result in significant savings. Pre-1985 toilets commonly use 20 L of water per flush. Upgrading to a ULF toilet will reduce water consumption by 23,000 L/person/year. For later model toilets (13 L), the savings will be closer to 13,500 L/person/year[1]. An estimated cost of replacement is $180/toilet. Annual savings would range between $13 and $23 per person or as much as $75 per suite[2].

[1] Assumes 4.5 flushes / person / day.
[2] Assumes $1.00/cubic meter water charge.

Showerheads and Faucets

Installation of low flow showerheads and faucet aerators will save approximately 12,000 L/person/year or $12 per person annually. Replacements costs are estimated to be $20/suite. It is important to note that aerating-type showerheads create a cooler spray pattern and greater draughts. Users compensate by increasing the ratio of hot to cold water. This may offset energy savings from reduced hot water use.

Washing Machines

Washing Machines can be adjusted to allow cold rinses only. Modifications to rinse cycle water temperatures will average $100 per machine. In terms of energy cost savings, payback will be in the order of 6 to 12 months. Quaified personnel are required to make machine modifications.

Leakage

A leak of one drop per second will amount to 9,000 liters per year. This represents $9 per fixture and $45 for hot water fixtures. Regular maintenance of water fixtures will reduce leakage and minimize municipal water and sewerage service and energy costs. Kitchen and bathroom taps should be replaced every two years. Replacement costs are approximately $5 per fixture.

Installation of washerless taps can be undertaken as old tap sets require replacement. These will significantly reduce labour costs for regular washer replacement. They typically cost 30-50% more than conventional taps.

Toilet replacement may eliminate undetected leakages, commonly at the flapper valve on older toilets.

Exterior Water Use

For the typical high-rise lot, rain sensor equipment may cost approximately $150. Savings from water conservation would be 12-15% or $125 per season (at $1.00/$m^3$). Simple payback would be 1.5 years.

Sources of Information

- *Water: No time to waste - A Consumer's Guide to Water Conservation* , Environment Canada 1995.
- *A Survey of Ultra-low Flush Toilet Users*. Prepared for the Los Angeles Dept.; of Water and Power by the Wirthlin Group, 1995.
- *The Potential for Water Efficiency Improvement in Multi-Family Residential Buildings in Canada*, CMHC, 1997.
- *The Performance of Ultra-Low-Volume Flush Toilets in Phoenix*, Journal of American Water Works Association (AWWA), Vol. 81, No. 3, Anderson, D.L. and Siegrist, R.L., 1989.
- *Residential Water Conservation; A Review of Products*, Processes and Practices, CMHC, 1991.
- *An Ecological Approach to Site and Subdivision Design,* Alberta Municipal Affairs, 1993
- *Energy and Water Efficiency in Multi-Unit Residential Buildings*, Technical Manual, CMHC, 2000.
- *Case Studies of Potential Applications of Innovative Residential Water Wastewater Technologies* , CMHC, 1999.
- *Water Quality Guidelines and Water Monitoring Tools for Residential Water Reuse*. CMHC,1999.
- *Innovative Water and Wastewater Management*, CMHC, 1998.
- *An Application Guide for Water Reuse Systems*, CMHC,1998.
- *Regulatory Barriers to On-site Water Reuse,* CMHC, 1998.
- C*MHC Water Conservation Page @* http://www.cmhc-schl.gc.ca/rd-dr/en/water-eau/index.html

LANDSCAPE PRACTICES

Related Topics

Low Slope Roofing Systems
Space Heating and Air Conditioning
Site Planning
Water

THE ISSUES

Approriate and well-considered landscape practices offer designers the opportunity to achieve increased levels of occupant comfort as well as cost savings through reduced resource consumption. Consideration should be given to water conservation, seasonally appropriate design decisions and stormwater management.

Across Canada, water use more than doubles in the summer months. Most of this increase is due to the watering of lawns and gardens, car washing and the filling of swimming pools. This is typical of suburban areas, but highrise water consumption also contributes to increased summer water use. This is the case for buildings with extensive landscape watering requirements. Through water conservation practices in landscape design, this phenomena can be reduced.

Energy consumption in highrise residential buildings can also be reduced through thoughtful landscape design practices. Plants provide the most economic means of modifying microclimate around a building, and represent a small investment for large energy savings. Appropriate and well-placed plants will have an effect upon energy consumption. Other devices such as landscape structures and site grading are also available to the landscape architect, and when employed correctly, can result in further energy savings.

Stormwater management represents a significant cost to municipalities, via infrastructure required to transport and treat run-off. It also represents a cost to the environment through non-point source pollution. This is the transfer of pollutants from roadways and parking lots directly to water bodies via run-off. The landscape architect as well as the civil engineer are able to offset these costs by using appropriate best management practices for stormwater management. Many on-site devices are available for slowing and filtering stormwater. Other strategies include minimizing the amount of run-off from a site as well as re-using it.

Key issues considered in this section include:

- Water-efficient landscape practices
- Energy-efficient landscape practices for Summer and Winter
- Stormwater management practices.

DESIGN CONSIDERATIONS

Water-Efficient Landscape Practices
Reducing watering requirements by at least 50% is achievable when specifying a water-efficient landscape. There are many water conservation practices that can achieve such reductions.

Rainfall Storage and Reuse

Rain diverted through downspouts into storage devices (cisterns, rain-barrels) can be used for irrigation. The “Rainfall Capture Potential” table provides an estimate of the rainwater volume collectable from typical high-rise buildings across Canada. Storage devices range in size. The Mountain Equipment Co-op Building in Ottawa has a rain storage container of 65,000 liters. It is 2.4 m (8 ft) in diameter and 6.0 m (20 ft) high.

Considering that high-rise buildings can consume an average of 13,000,000 litres annually[1], rain collection for indoor use does not seem significant. However, rain collection would likely meet a high-rise building’s irrigation requirements. Rain collection for irrigation helps to lower water demand during summer months when consumption is at its highest.

Locally Hardy Plants

Match plant species to their local conditions. Locally hardy plant species, such as native plants,

Rainfall Capture Potential*

City	Annual Rainfall (mm)	Annual Rooftop Rainfall Volume (L)
Vancouver	1106	703,000
Calgary	420	267,000
Regina	378	240,000
Winnipeg	513	326,000
Toronto	766	486,000
Montreal	1036	701,000
Halifax	1394	885,000

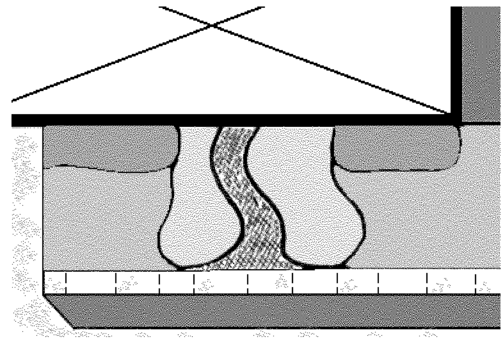
are adapted to their indigenous climate. Under conditions similar to their native habitat, they have the ability to survive without human intervention. These species are therefore ideally suited to water conservation and are less costly to maintain. Native plants are also more resistant to disease and infestation, and will benefit local insects and birds (see Appendix 2: A Selection of Water Efficient Plants, Trees and Shrubs in Household Guide to Water Efficiency, CMHC 2000).

Hydrozone Planting
Group plants according to their water requirements. This will ensure water is not being wasted on plants whose needs do not warrant the frequency or quantity of adjacent plants with higher watering-demands.

Drought-tolerant Plants
Water-efficient plant specifications should include the use of drought-tolerant species. Such plants, while not exclusively native species, require less water than plants of similar size and structure. Drought-tolerant species lists will vary according to hardiness zones. These plants are often used in a type of landscape called a Xeriscape (from the Greek 'xeros' meaning dry).

Water-efficient Irrigation
Drip irrigation is more water- efficient than sprinkler irrigation. Sprinklers can lose approximately 25% to 50% of water content to wind and runoff[2] . Drip irrigation reduces

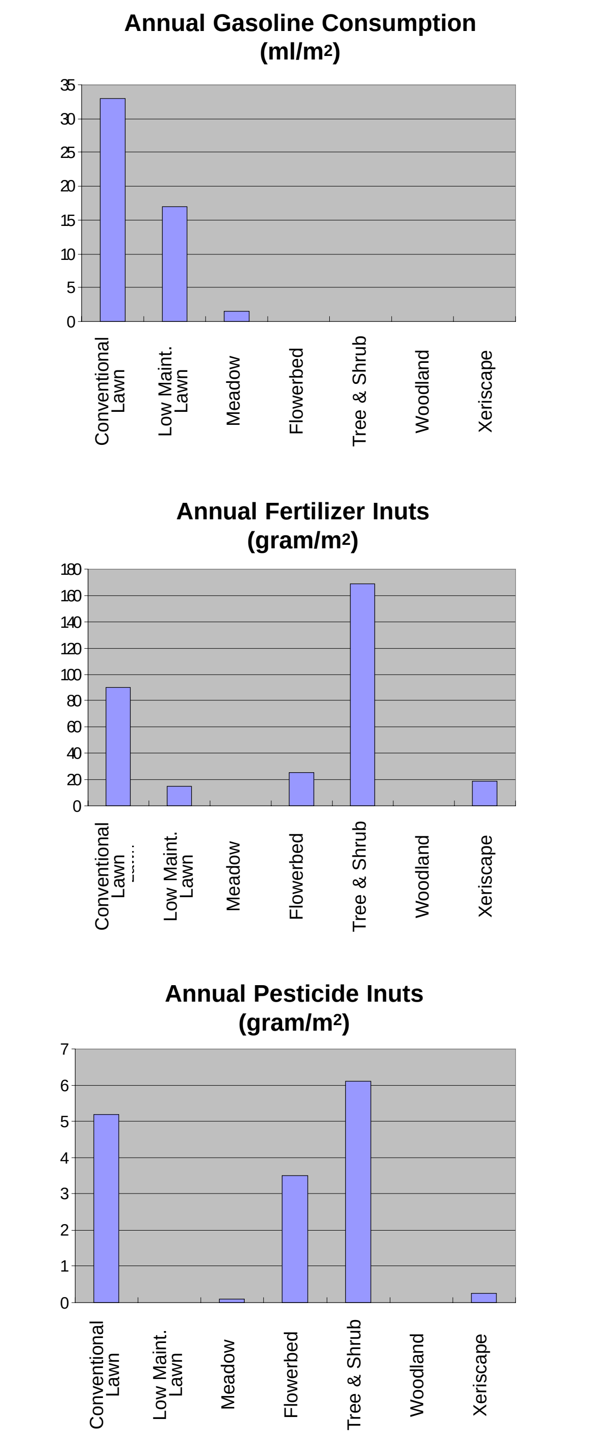
Water-Efficient Landscaping



1 Native plants requiring irrigation only during establishment
2 Continuously rooting groundcover with low water requirements
3 Exotic shrubs with moderate water requirements
4 High use area with draught-tolerant turfgrass
5 Water permeable paving

evaporation through the application of water directly into the soil. It also limits irrigation to planted surfaces only, avoiding the unnecessary watering of sidewalks and pavement. Drip irrigation can save 50% to 75% compared to a sprinkler system. Also, rain sensors prevent over-watering. Small and inexpensive rain sensors can be installed to prevent automatic watering systems from activating during or after rainfall. Installation costs can be recouped within two years through water costs savings.

Lawns
Lawns typically require 25 mm (1 in.) of water per week. This can add up to 750,000 litres annually for a typical high-rise building[3] . In general, groundcovers require less water because they have a larger root zone from which to draw soil water. High-use areas may be impractical for groundcovers, however. In such cases, drought-tolerant turfgrasses are available and should be used (see Appendix 3: Turfgrasses for Canadian Lawns in Household Guide to Water Efficiency, CMHC 2000). Also, only fertilize lawns once in the spring. Over-fertilized lawns grow beyond their limits and require increased watering.



Source: Definitely in My Backyard, CMHC 2000

Mulching

Besides controlling weeds, mulches retain soil moisture levels and prevent soils from overheating and drying-out by reducing evaporation. Mulches will also increase the wetted surface area of soil under the mulch[4] . Over time, organic mulches will also breakdown and improve the structure of soils, improving water infiltration. Proper mulching practices will reduce the quantity of water required for irrigation, it can reduce evaporation and run-off by 75% to 90% over unmulched areas[5]. A mulching depth of 10 cm will result in optimum moisture retention[6] .

[1] City of Vancouver data 1997-2000, 80 suite building.
[2] Ontario Home Warranty Program, The High-Rise Residential Construction Guide, p.10-7
[3] Energy and Water Efficiency in Multi-unit Residential Buildings, CMHC. p.7-2
[4] BC Trickle Irrigation Manual, Ministry of Agriculture and Fisheries. p.5-5,
[5] Santa Monica Green Building Design and Construction Guidelines, Sheltair Group 1999, p. 12.
[6] About Your House – Water-saving Tips for Your Garden, CMHC. p.2

Stormwater management represents a significant cost to municipalities, via infrastructure required to transport and treat run-off. It also represents a cost to the environment through non-point source pollution. This is the transfer of pollutants from roadways and parking lots directly to water bodies via run-off. The landscape architect as well as the civil engineer are able to offset these costs by using appropriate best management practices for stormwater management. Many on-site devices are available for slowing and filtering stormwater. Other strategies include minimizing the amount of run-off from a site as well as re-using it.

Key issues considered in this section include:

- Water-efficient landscape practices
- Energy-efficient landscape practices for Summer and Winter
- Stormwater management practices.

Energy-efficient Landscape Practices

A recent study by CMHC looked at the amount of fuel, fertilizer and pesticide use by a variety of landscapes and found that low-maintenance lawns required less energy inputs than conventional lawns. Woodland-type gardens performed the best, however. The low maintenance lawn cosists of hardy, drought-tolerant, slow-growing grass and broad-leafed species, such as clover, that do not require frequent mowing. The woodland shade garden is composed of native trees, shrubs and groundcovers. Xeriscapes and Meadows were also found to require minimal energy inputs. Xeriscapes consist of plants suited to local rainfall conditions and require almost no watering. Meadows feature native grasses and wildflowers. Graphs at the left illustrate these comparisons.

Summer

Use plants and landscape structures to reduce summer heat gain by:

- Shading the building from direct solar radiation,
- Diverting or channelling air movement away from or towards the building,
- Creating cooler temperatures near buildings through evaporation and transpiration.

The Heat Island Effect

The heat island effect is the phenomena of higher temperatures occurring in urbanised areas relative to their suburban and rural surroundings. On warm summer days, the air in a city can be up to 5°C hotter than its surrounding areas. One reason for this is less vegetation in urban areas to intercept solar radiation, and cool the air with the transpiration process. Transpiration is the process of water loss to the atmosphere through living-plant surfaces.

At the microclimate level, vegetation can directly reduce surface temperatures through shading and the interception of solar radiation. Trees can reduce the temperature in their immediate vicinity by up to 5°C from shading alone. One mature beech for example, will shade 170m^2 of surface area[1] . Air temperatures above vegetated areas can be up 8 to 14°C lower than over asphalt or concrete areas of equal size. As a result, urban vegetation can alter the surface energy balance within a localised area and result in lower ambient temperatures.

On a local climate scale, vegetated areas will lower air temperatures through the process of transpiration. A 21-meter canopy tree, for example, can transpire the equivalent of 375 litres of water per day, which has the cooling effect of 5 air-conditioners operating for 20 hours[3] . This cooling effect is the result of evapotranspiration and lowers ambient daytime temperatures. Tree canopies can also slow the escape of heat from urban surfaces at night. Combined, these effects lower ambient temperatures.

More vegetation lowers air temperature, reducing the need for air-conditioning and lowering energy consumption. This translates into direct cost savings to residents. It also can reduce global warming (less electrical demand implies less burning of fossil fuels at power generation plants).

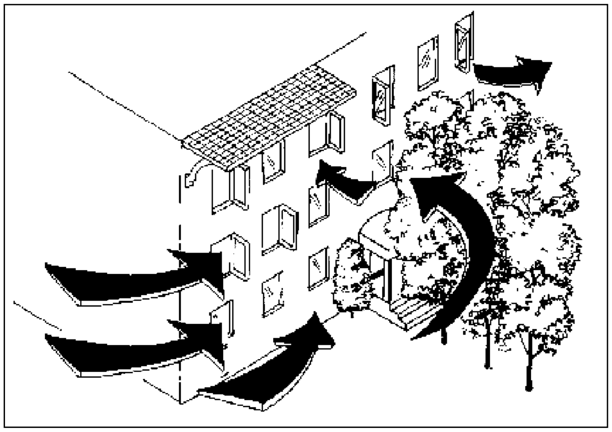
Recommended SummerPractices

1 Use rooftop plantings to reduce heat absorption into buildings through their roofs (see Winter Practices number 1).

2 Plant broad-leaf deciduous shade trees to intercept solar radiation near ground level parking areas and other paved surfaces. Acer platanoides will allow only 10% of solar radiation to penetrate its canopy in summer, while allowing 65% in the winter[4]. Shaded areas can be as much as 10oC cooler than areas in full sun.

3 Plant self-supporting vines to climb south-facing walls to reduce summer solar gains. A 16-cm blanket of plants can increase the R-value of a wall by as much as 30%[5] . Less vigourous species will not compromise cladding.

4 Plant deciduous trees to shade the first 3 to 5 storeys of an apartment building's south and/or west elevations.



5 Plant trees upwind of natural ventilation outlets (including opening windows) to create local low-pressure areas that will enhance ventilation by drawing air out of the building.

6 When appropriate, plant low maintenance groundcovers in place of paved surfaces to lower heat absorption.

7 Minimize the use of dark, paved areas and use light-reflective paving materials to reduce heat absorption.

8 Use pergola and trellis structures on south and west walls only, to ensure light penetration in winter.

9 Plant drought-tolerant, slow growing turfgrass and plant species that have lower maintenance requirements.

10 Use rooftop plantings to cool rooftop air temperatures near mechanical ventilation system air-intakes.

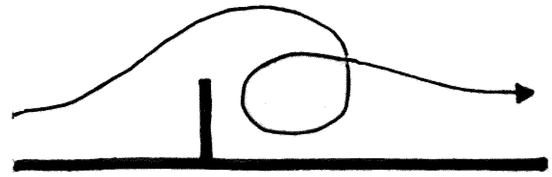
11 Photovoltaic (solar-powered) outdoor lighting is available as an energy-saving alternative.

[1] Minke, G. und Witter, G.; Haeuser mit Gruenem Pelz, Ein Handbuch zur Hausbegruenung; Verlag Dieter Fricke GmbH, Frankfurt.
[2] http://eande.lbl.gov/HeatIsland/Vegetation/Evapotranspiration html
[3] Ministry of Energy, Landscape Planning for Energy Efficiency, p. 56.
[4] Minke G et al.
[5] Brown, R. and Gillespie,T. Microclimate Landscape Design, p.116.

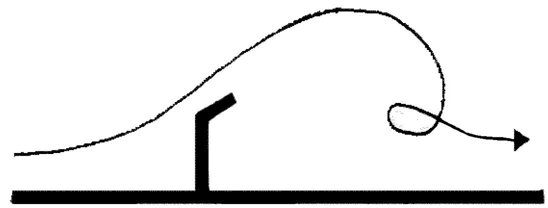
Winter

Heating costs in winter can be decreased by properly locating plants and landscape structures so that:

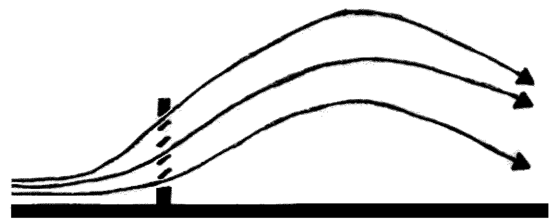
- The amount of direct solar radiation received by the building is maximized,
- The effects of cold winter winds are minimized.



Solid vertical fence creates high turbulence

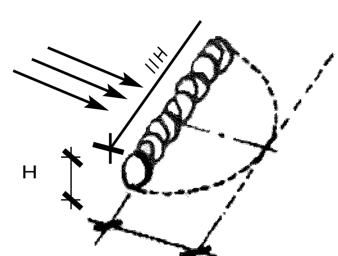


Solid fence with tilted top increases shelter distance

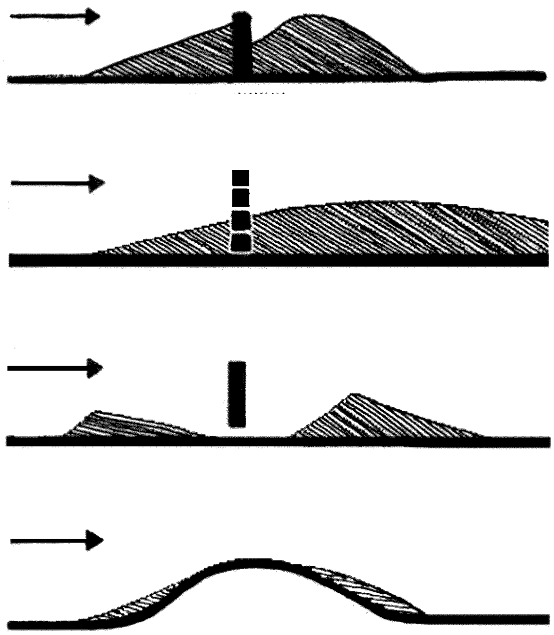


Permeable fence with slanted louvres directs windflow upwards and minimizes turbulence

Plants can provide effective shelter. Maximum wind protection occurs with a barrier length of 11 to 12 times its height.



Wind Shadow Length



Snow accumulation associated with different types of barriers.

There is an emperical relationship between the length of drift and the height and density of the barrier: $L = \frac{36 + 5h}{k}$

where L=drift length
h=barrier height (ft.)
k=screen density and
50% density=1.0
70% density=1.28

Reducing the Effect of Imperviousness

1. Maximize the percentage of permeable surface and green space to allow more percolation of stormwater into the ground.

2. Minimize directly connected impervious areas.

3. Maximise the amount of runoff slowed and absorbed by vegetation and permeable areas by placing roofs and pavement at higher points in the landscape.

Recommended Winter Practices

1. Rooftop plantings can provide additional insulation to buildings. A 20-cm growing medium plus a thick layer of grass (20-40cm) has an R-value of 20[6] .

2. Plant coniferous shelterbelts perpendicular to winter winds. Maximum wind blockage occurs with a shelterbelt length equal to 11 to 12 times its height. Maximum wind blockage occurs at a distance of 3-5 times the height of the shelterbelt.

3. Block cold winter winds near building entranceways with conifer trees and/or structures. A staggered planting plan along the entrance walkway will minimize cold winds blowing directly into a building's entrance.

4. Use fencing, shrubs and coniferous plantings to decrease snow accumulation near walkways

5. Water must be drained well away from building foundations to prevent damage from frost/thaw action.

[6] Liesecke, H-J., Krupka, B., Brueggemann, H.; Grundlagen der Dachbegruenung, Zur Planung, Ausfuhrung und Unterhaltung von Extensivbegruenungen und Einfachen Intensivbegruenungen, Patzer Verlag, Berlin-Hannover.

Stormwater Management Practices

Imperviousness

Factors affecting runoff quantity and quality include soil type, land cover, slope and imperviousness. Imperviousness radically alters the water balance of a site by increasing runoff volume and peak discharge. This is a major contributor to water pollution. Urbanisation results in more hard surfaces, soil compaction and less stormwater absorption. Under forested conditions only about 6% of total rainfall becomes runoff. Within urban settings, as much as 90% of rainfall can become runoff.

There is an inverse relationship between imperviousness and runoff quality. Runoff from urban sources represents a threat to receiving water bodies. It contains high concentrations of nutrients (phosphorous, nitrogen), suspended solids, organic carbon, bacteria, hydrocarbons, trace metals, chlorides (salt) and debris[1] . Runoff also results in increased peak storm discharges causing erosion and sedimentation.

Even small increases in impervious cover can effect water bodies. For example, stream degradation occurs even when imperviousness increases within a given watershed by as little as 3 to 10%[2] . The imperviousness of a high-rise building lot is typically 50-70%[3] , but can be as high as 85%[4] . While the highest proportion of urban imperviousness is transportation-related (60% to 70%)[5] , decreasing lot imperviousness is still an important overall strategy.

-Best Management Practices for Stormwater

Best management practices (BMPs) are accepted methods for reducing runoff quantity and increasing its quality. In order to decrease the impacts of urbanisation, many communities in North America have adopted these practices (Bellevue, WA; Baltimore, MD). Detaining water on-site provides the fundamentals for water quality treatment. Urban phosphorus loads can be reduced when BMPs are used. BMPs include stormwater ponds, wetlands, filters and infiltration practices. BMPs can reduce phosphorus loads by as much as 40% to 60%[6] and offer added amenity.

-Runoff Diversion

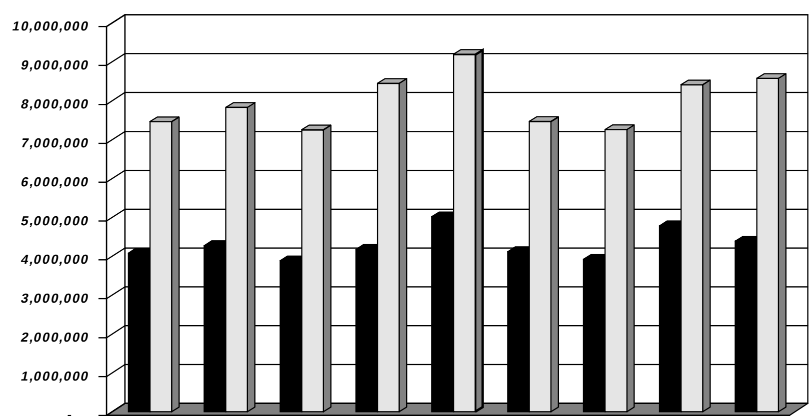
Where water runs from impervious surfaces onto absorptive surfaces, runoff is minimised. By using curbs and berms to divert stormwater from impervious surfaces and reusing it when possible, urban runoff can be greatly reduced. One method for accomplishing this is to direct rainwater into swales, infiltration basins and trenches where it can infiltrate into the groundwater. One of the more common stormwater management mechanisms is the drywell or ‘french drain’. Manufactured sediments traps are also available that intercept runoff from drainage areas, and slowly release it while trapping sediments.

-Land Cover

Complex land covers result in less runoff because they tend to intercept more precipitation. The most complex land covers are highly layered plant communities with vast amounts of leaf area that must be wetted before runoff occurs. Urbanisation tends to lead to a simplified land cover, causing an increase in runoff volumes.

Green Roofs

Green roofs offer three important benefits concerning stormwater management. They retain, filter and slow down stormwater. Green roof systems have been observed to reduce stormwater discharge by as much as 90%[7] . On average, green roofs retain 70%-100% of summer precipitation, and 40-50% of winter precipitation



	Feb to May	June to Sept	Oct to Jan	Feb to May	June to Sept	Oct to Jan	Feb to May	June to Sept	Oct to Jan
Highrise 1	4,082,30	4,274,81	3,886,96	4,178,55	5,019,36	4,119,10	3,920,93	4,784,39	4,388,05
Highrise 2	7,458,27	7,833,37	7,247,36	8,450,53	9,183,76	7,459,68	7,258,68	8,413,73	8,577,93

This graph shows water use by two residential high-rise buildings in Vancouver between 1997 and 1999. “Hi-Rise 1” has 76 suites, “Hi-Rise 2” has 120 suites. Both have outdoor watering systems.

Summer water use for both buildings increased total consumption by an average of 13% or approximately 2225 litres/suite/year.

that falls on them. A green roof acts as a natural filter for discharge that does occur by filtering out heavy metals and nutrients carried by rainwater. Its absorptive quality (10-15 cm of runoff retained with a 20-40 cm layer of growing medium[8]) also slow downs discharge, reducing the risk of flooding.

[1] Maryland Department of the Environment, Maryland Stormwater Design Manual, Vol.1, p.1.4
[2] Chillibeck, B., Urban Drainage Planning and Stormwater Management, Dept. of Fisheries and Oceans
[3] Harris and Dines, Time Saver Standards for Landscape Architecture, p. 330.23
[4] City of Santa Monica, Report to Council on Urban Runoff Reduction, p.6.
[5] Bay Area Stormwater Management Agencies Association, Start at the Source, p.17.
[6] Schueler, Tom, The importance of Imperviousness from Watershed Protection Techniques Vol. 1, No. 3 - Fall 1994
[7] Thompson, W., “Grass-Roofs Movement” in Landscape Architecture, May 1998, Vol.88, No. 6, pp.47-51.
[8] Peck, Callaghan, Kuhn, Bass. Greenbacks from Green Roofs: Forging a New Industry in Canada. CMHC, 1999. p.28

Sources of Information

- *About Your House–Water Saving Tips for Your Lawn and Garden*, CMHC 2000
- *Start at the Source*, Bay Area Stormwater Management Agencies Association, USA, 1997.
- *Microclimate Landscape Design*, Brown, Robert and Terry Gillsepie. John Wiley & Sons, USA, 1995.
- *Definitely in My Backyard–Making the Best Choices for You and the Environment*, CMHC, 2000 @ http://www.cmhc-schl.gc.ca/cgi-cmhc/enfrmsite.pl?target=/publications/en/definitely/index.html
- *Energy and Water Efficiency in Multi-Unit Residential Design*, Draft Version, CMHC, January 1998.
- *Energy-Efficient and Environmental Landscaping*, Appropriate Solutions, Moffatt, Anne Simon and Marc Schiler. USA, 1993.
- *Creating a Prairie Xeriscape: Water-Efficient Gardening*, Williams, Sara, University of Saskatchewan Press, Canada, 1998.
- *Alternative Stormwater management practices for residential projects*, CMHC @ http://www.cmhc-schl.gc.ca/rd-dr/en/water-eau/stormwater.htm
- *Sustainable Landscape Construction*, J. William Thompson and Kim Sorvig. Island Press, Washington DC, 2000.
- *Design Guidelines for Green Roofs*, @ http://www.cmhc-schl.gc.ca/en/imquaf/himu/himu_002.cfm

OCCUPANT COMFORT - NOISE

Related Topics

Air Barriers

THE ISSUES

Noise emanating from neighbouring apartments, common areas, building mechanical and plumbing systems and noise from outdoors can reduce occupant comfort in high-rise buildings and can also become the source of litigation.

Noise reaches building occupants through the airborne transmission of sound, and through the transmission of vibrations through the structure of the building.

The sources of disturbing noises are many. They include exterior traffic and aircraft noise, and interior noises from neighbouring suites generated by TVs, stereos and other appliances. The building systems themselves are also the sources of mechanical, plumbing, fan, diffuser and other HVAC noises.

Recent research for CMHC and IRC has resulted in the development of recommended practices which can minimize noise problems in multi-unit apartment buildings.

STC Ratings

STC (Sound Transmission Class) ratings are used to describe the performance of assemblies in reducing airborne sound. While higher than current Code requirements, the STC ratings presented in the chart below will provide enhanced building comfort.

STC Ratings of Various Assemblies:

Assembly Type	STC Rating
Floor/Ceiling	55 db
Common Suite Walls	55 db
Exterior Wall Assembly	60 db

IIC Ratings

The IIC (Impact Insulation Class) rating applies to noise tranmission due to structural impact and vibration through floor and celing assemblies. The ratings in the attached graphic illustrates improved design objectives.

DESIGN CONSIDERATIONS

Noise control strategies must be addressed at the design stage, as retrofit costs to improve acoustic performance can be very high. Designers must consider the noise implications of the architectural, structural, mechanical, and electrical design. The designer must address sound transmission through airborne and structural routes.

Verification

Sound levels should be verified by field measurements using the ASTME336 standard, allowing construction defects to be corrected prior to occupancy.

Doors

Noise transmission is a common complaint in high-rise buildings with pressurized corridors. More innovative ventilation strategies (such as compartmentalized suites) may allow for better sealing of entry door systems. The accompanying chart demonstrates the potential noise reduction from alternative door assemblies.

Sound Insulation of Conventional Doors:

Door Type	Surface Weight (PSF)	STC (With Gaskets)
Solid-core Wood (13/4”-21/4”)	5.2-6.3	28
Hollow-core Steel (18ga.)	25	26
Filled Metal Door	6.5	27
Sound Rated Door	8	32

Windows

Windows have typically been the weakest acoustical link in exterior walls. Improvements in windows for thermal comfort purposes (for example multi-pane glazing and thermally broken frames) have also improved their acoustical performance.

Sound transmission (especially when close to transportation routes) can be reduced by increasing glass thickness (laminated glass), and increasing the width of the air space between panes. These two strategies can increase the STC rating by as much as 8 to 10 points. Eliminating rigid mechanical coupling of the window to the frame structure, using resilient or gasketed mounting, will further enhance performance.

Air-Borne Noise

Strategies to deal with air-borne noise include:

- selection of envelope and party wall assemblies with good sound insolation characteristics.

Impact Noise

Strategies to reduce noise transmitted through the structure include:

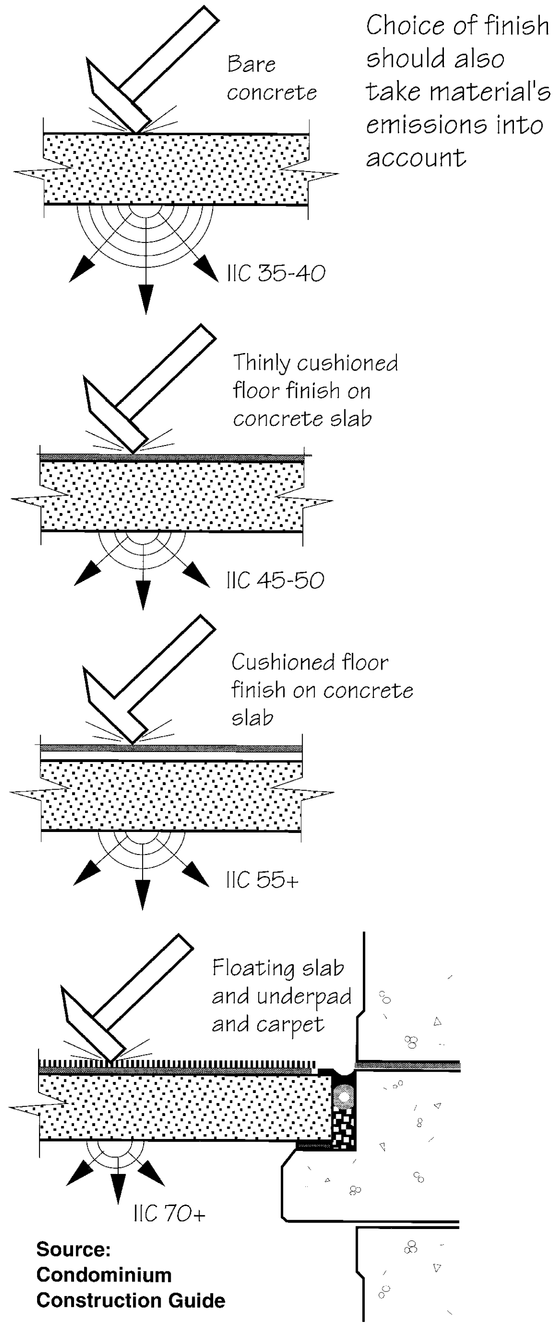
- providing an improved floor design e.g., a floating floor above the structural floor and/or absorbent materials within the floor cavity,
- providing an increase in floor layer mass and resiliently suspended ceilings,
- reducing the impact at source through the use of resilient materials such as carpet and underlay (with due consideration to their effect on IAQ),
- avoiding flanking noise transmission through structure by using resilient connections.

Mechanical Equipment Rooms[1]

Noise control measures for mechanical equipment rooms adjacent to apartment units include:

- choose equipment designed for low noise emissions,
- use a floating concrete floor in the mechanical room,
- use resiliently suspended secondary isolation ceilings in the mechanical room,
- use cavity wall construction in the mechanical room,
- use sound absorptive treatment of the mechanical space walls and ceilings,
- eliminate structural connections to avoid flanking noise transmissions.

Impact Insulation Class Ratings



Source: Condominium Construction Guide

Plumbing Systems

Measures for controlling noise resulting from plumbing assemblies include:

- maintain water pressures at a maximum of 35 psi, and velocities below 1.8 m/sec in branch lines and 3.0 m/sec in main lines[2] ,
- the use of plastic piping in the supply network will decrease noise transmission[3] ,
- supply pipes should be supported by vibration isolation mountings of resilient material,
- where pipe ‘cross-overs’ occur in occupied space, pipes should be housed in double gypsum board boxes and lined with fibreglass batt insulation.

Installation

While good accoustic design is vital, it should be noted that poor installation techniques can negate good design practices. For example, debris and waste construction material can create a noise bridge that results in flankning noise transmission despite a correct overall design. Poorly installed resilient channels are also a common problem (often upside-down or installed into structural elements). Proper onsite training and demonstrations for workers involved with walls and plumbing equipment would help to reduce poor installation.

[1] Ontario Home Warranty Program, The High-Rise Residential Construction Guide 1995, p6-25
[2] Ontario Home Warranty Program, The High-Rise Residential Construction Guide 1995, p6-26
[3] CMHC, Recherche sur les bruits de plomberie dans les edifices a logements 1996

Sources of Information

- *Bibliography on Noise*, CMHC.
- *How to Reduce Noise Transmission Between Homes (Apartments)*, NRC/IRC. National Research Council Canada / Institute for Research in Construction.
- *Ontario Home Warranty Program High-Rise Residential Construction Guide 1995*, The Ontario Home Warranty Program.
- *Noise Isolation Provided by Exterior Walls in Wood Construction*, CMHC, 1998
- *Plumbing Noise in Multi-Dwelling Buildings*, CMHC, 96-223.
- *Household Appliance Noise in Multi-Unit Buildings*, Décibel Consultants Inc., CMHC, 1992.
- *Noise Isolation provided by Access Doors in Multi-Dwelling Building*s, MJM Acoustical Consultants Inc. for CMHC, 1993.
- *Sound and Fire Performance of Fire Stops in Multi-Family Dwellings: Transmission via Fire Stops*, CMHC, 1997.

REGIONAL DIFFERENCES

Site Planning

The basic design considerations and approaches for the environmental performance of buildings in terms of site planning are the same for all regions across Canada, and have been addressed in the Site Planning section. For example, while the specific natural features of any given site will differ, the basic concept of designing buildings that work in concert with existing contours, stream flows, vegetation patterns, and so on does not.

A key issue that will vary by region is the orientation of the building to take account of seasonally varying needs for light and heat. In Canada, while climate varies by regions, most buildings nonetheless have more significant winter heating loads than they do summer cooling loads, and thus the general approaches to building orientation will be similar. The general rule-of-thumb of ensuring maximum access to sunlight for passive and active solar strategies by orienting buildings SSE to SSW 5% to 15% will be relevant to most buildings.

The variation of wind patterns by region should also be considered in order to optimise possibilities for natural ventilation. While rules-of-thumb exist for incorporating natural ventilation strategies into the design of high-rise buildings, these tend to be impacted by micro-climatic influences (surrounding buildings, local storm patterns, etc.) as much as by regional directional wind patterns. Consideration of building orientation in terms of wind patterns should therefore be conducted at a site-specific level.

Materials Selection

Historically, the materials used in the construction of buildings were a direct reflection of the local climate combined with the materials readily available and appropriate for building. Modern technology and transportation systems have altered this situation, and the selection of materials is rarely a result of these regionally-based factors alone. Indeed, cost has emerged as one of the key influences on the choice of materials to be used in the construction of a building. From the perspective of environmental performance, however, a return to the traditional method of selecting building materials would be prudent.

While all of the issues identified in the Materials Selection section should always be considered when specifying materials, the key issues to consider from a regional point of view are durability and embodied energy. In terms of durability, regional climate differences are important because they will impact on the long-term performance of the materials. For example, wind can cause mechanical erosion, and thus in regions (particularly coastlines) where heavy winds are frequent, tougher finishes will be required. Another example is that of the impact of wetting-freezing regimes on porous masonry. Where such conditions prevail, it is important to use denser brick and cement if masonry is to be used. As well, rain can have a significant impact on materials due to the acidity it contains, leading to the corrosion of aluminium and the rusting of ferrous metals.

The second key issue to consider from a regional point of view is that of embodied energy. The energy required to transport materials to a construction site contributes a significant amount to the total embodied energy contained in a material, and thus, using locally-produced materials can have a notable impact on reducing the embodied energy of a building. From this perspective, the selection of materials should be predicated in large part on what is readily available and appropriate that does not have to be transported over long distances. This applies also to the use of salvaged and / or recycled materials, which should be considered appropriate for inclusion only if they are available in the local region. Transporting salvaged timber over thousands of miles would result in negligible environmental benefits since the energy embodied in transportation would negate the production energy saved.

Multi-Family Residential Water Charges ($/m^3)	
City	**$/M3**
Victoria, BC	02.92
St. John's, NFLD	0.357
Saskatoon, SASK	0.388
Vancouver, BC	0395
Lethbridge, AB	0.448
Edmonton, AB	0.704
Winnipeg, MA•	0.777
Toronto, ONT	1.104
Yellowknife, NWT	3.14

Source: Env. Canada etc

Solid Waste

Strategies for improving the environmental performance of buildings in terms of solid waste are on the whole not sensitive to regional variation, with the exception of the generation of yard waste. In regions with a more temperate climate in the winter, such as the west coast, it is likely that greater amounts of organic waste will be generated in the winter than in colder climate regions. This does not, however, alter the basic design considerations and approaches.

Water

Regional differences affect how water pricing is determined across Canada. In general, apartment buildings are metered accounts as opposed to flat rate accounts. Prices are determined by municipal authorities as the amount required to cover the costs of operations and maintenance of treatment plants, pumping stations and water conveyance systems. The graph at left shows differences for multi-family units for some Canadian cities.

Landscape Practices

Regional variations will greatly affect landscape practices. Vegetation will vary according to plant hardiness zones. Plant hardiness zones are defined primarily by precipitation levels, the frost-free period and growing degree-days (annual sum of normal degree-days above 5° C). In general, coastal climates tend to have longer summers than interior regions and thus will use more outdoor water and sustain longer maintenance periods. These areas may also experience less watering restrictions due to higher precipitation volumes, although this will depend on many other factors. These regions will benefit the most from landscape practices that consider frequent rainfall occurrences. Conversely, the Prairie regions have shorter summers and therefore less residential outdoor water use (per m^2). These regions, with temperate climates, will benefit from landscape practices for summer shading and snow accumulation in winter. Dry, arid parts of Canada may experience more water restrictions due to lower water supply recharge in combination with higher vegetation watering requirements. These areas will benefit the most from solar radiation interception practices. Northern regions use the least amount of outdoor water, due the least number of growing degree-days in Canada. These regions benefit from appropriate landscape practices that deal with snow accumulation and the control of winter winds.

CASE STUDY

Amsterdam's Carfree Public Housing Project Has Sustainable Edge

GWL-TERRIEN DEVELOPMENT

In 1993, the Amsterdam borough of Westerpark announced a car-free housing project for 600 dwellings. The 17 apartment buildings (which include two 10-storey blocks) were completed in stages between late 1996 and1998. The project is located 3 km from the city centre at the terminus of an existing tram line and adjacent to early 20th century developments. The GWL-terrein development was integrated very closely with the surrounding district. Each existing street approaching the site from the east or south was extended through the project as a pedestrian walkway that knits the neighbourhood together. Most apartments are 2 or 3 bedroom units. The project includes housing for disabled children, studio apartments for artists, pensioner apartments and a housing commune.

ENVIRONMENTAL INNOVATIONS

The project has many 'sustainable' design features, including: (1) sensitive site planning and building siting that integrates the site with the adjacent neighbourhood, preserves greenspace and views to greenspace, (2) greywater recycling and rainwater reuse, (3) greenroofs, (4) organic food production from communal gardens, (5) recycling facilities that include composting, (6) housing for a wide demographic including the elderly, (6) a cogeneration installation and a heat pump.

The GWL-terrein makes use of a 6 hectare site, formerly used by the municipal water utility (GWL). Some of the old buildings were preserved for cultural purposes and local business, and an operational water tower was integrated as a landmark. Small shops and services including an Internet café and restaurant and TV studio are in the old waterworks buildings. Building preservation and conversion was important for heritage reasons as well as for avoiding solid waste generation.

Apart from its car-free character, the development has various ecological features ranging from landscaped roofs, stormwater detention areas, habitat-rich landscape planting and a ban on timber from non-sustainable production. The low allocation of space for parking, combined with the lack of paving for vehicles, enabled an interconnected system of high-quality open spaces penetrating the entire site, a significantly lower amount of impervious area than conventional development and higher habitat value for local vegetation. This was achieved despite its relatively high density of

150-200 persons per hectare. Recycling facilities are also available . Recycleables are separated into four categories (including organics) and collected in underground containers at the perimeter of the site.

Water conservation is achieved via rainwater collection for toilet-flushing as well as some greywater recycling for non-potable use. Low-flow toilets have also been installed.

Project Info

Location:	Amsterdam, Netherlands
Architects:	Kees Christiaanse Architects & Planners Dobbelaar de Kovel de Vroom Architecten Atelier Zienstra van der Pol WJ Neutelings Architectuur Meyer en Van Schooten Architecten
Site Area:	6 hectares
Number of Dwellings:	600 units
Completion Date:	1998
Further Information:	Opting for Change Sustainable Building in the Netherlands Aeneas Technical Publishers PO Box 356, 5680 AJ BEST The Netherlands www.aeneas.nl

CASE STUDY

Residential Reuse of an Office Building

THE PUNTEGALE

The Puntegale Building was home to South Holland's taxation authority for 40 years. The building was sold to the Rotterdam Foundation for Student Housing (Stadswonen) after the office moved to a new location. It now houses close to 500 residents, has 2500 m^2 commercial space and 18 offices. The monumental architecture of the 7 storey taxation office was preserved during the $17,000,000 conversion. Sustainable design measures implemented during the conversion included building air-tightness, high-efficiency glazing, passive solar heating, solar boilers and rainwater collection and reuse. These measures cost $1,300,000. The rootop solar collectors, for heating domestic hot water, occupy 80 m^2.

THE INNOVATION: BUILDING CONVERSION AND WATER REUSE

The entire shell and structure of the building was reused and converted into residential, commercial and office space. Not only was a distinct architectural style preserved, but a substantial amount of building material was diverted from the disposal process. Furthermore, new construction used as much prefabricated material as possible to avoid additional waste generation.

Another environmental benefit of the Puntegale project is water conservation from the collection and reuse of rainwater. Two tanks with a combined capacity of 62,500 m^3 collect and store rainwater. This water is used by residents for toilet flushing. The system saves an estimated 6 million liters of water per year from toilet flushing alone. In addtion to this type of water end-use, the Puntegale also offers optional connections to the rainwater system for clothes washing. Tenants have the choice of washing their clothes with municipal water or with rainwater. Potential water savings are significant, if only one-quarter of the dwelling units connect to the rainwater system, water savings would be another 3 million liters per year.

Project Info

Location:	Rotterdam, Netherlands
Architect:	De Jong Bokstijn Architect
Gross Floor Area:	20,000 m^2
Number of Dwellings:	201 units
Completion Date:	1999
Further Information:	Stadswonen Postbus 4057 3006 AB Rotterdam Phone +31 (0)10-402 82 00

CMHC SCHL

HOME TO CANADIANS

Canada

In This Section

Flexibility
- site and circulation
- dwelling unit layout
- additional unit features

Case Studies

The aging of the population, home care for persons with disabilities, and the shift to ambulatory medical care are trends that are now part of our everyday life. In 1991, 15% of the Canadian population had a mobility, agility, hearing, vision or speech impairment [1]. In 1986, 21% of Canadian households had at least one person with a disability, and this percentage reached 40% among households aged 65 years or older [2]. The number of seniors is expected to double between 1991 and 2015, up to 7.2 million people.

As a result of these trends, consumer needs are changing: residents are looking for well located, safer and better lit homes, as well as materials that are low-maintenance, equipment that is easy to manipulate, shorter travel routes to reduce fatigue, etc. [3].

From a better building standpoint, the architectural design of buildings and housing units, and the choice of materials and equipment should reflect these needs. This objective can be achieved with universal accessibility.

Through universal accessibility developers have the opportunity to offer a distinctive product that will better meet the immediate needs of consumers, thereby gaining a significant competitive advantage.

Developers can also add a fast-growing client group to their regular clientele: people concerned with greater flexibility and better accessibility of their premises. Many residents are effectively aware that they will be able to stay in their universally accessible dwellings if there needs change due to aging or a gradual or sudden appearance of temporary or permanent limitations. It will also be easy for them to accommodate friends or relatives with disabilities

Universal accessibility targets the entire population. For developers, it provides a way to offer added value and preserve permits buyers to preserve the value of their investment.

The recommended practices are simple. They are incorporated into the project right from the design stage. For the common areas of a building, they are in line with existing regulations. For the dwellings, the idea is to provide unobstructed circulation and strategically located manoeuvring areas. The choice of materials and equipment enhances performance and safety.

The recommended practices generate little or no additional expense, compared to conventionally designed units. It is advisable to incorporate them into all the housing units in a project, in order to provide the required flexibility at the time of sale or rental. These practices are to the advantage of everyone.

[1] Health and Activity Limitation Survey, Statistics Canada, 1986.
[2] A Socio-Demographic Profile of Canadians Experiencing Health or Activity Limitations, CMHC, 1991.
[3] Focus Groups to Examine Barrier-Free and Adaptable Housing Design, Hickling Corporation Inc. (1994).

FLEXIBILITY

Related Topics

Lighting and Appliances
Site Planning
Materials Selection

THE ISSUES

A person who uses a wheelchair has different needs than a deaf person and each can adapt their dwelling to meet their specific needs. However, a dwelling adapted for a deaf person will not suit a person using a wheelchair, and vice versa. An adapted housing unit is therefore a dwelling built or converted to meet the specific needs of an individual with a disability and does not address general market requirements.

The housing type that can globally meet the needs of persons with disabilities is a universally accessible dwelling. As such, most architectural barriers are eliminated at the design stage and at no additional cost. As a result, most people with disabilities can live in such a dwelling without having to make any conversions.

Nevertheless, it can happen that the characteristics of a universally accessible housing do not fully meet the specific needs of some individuals. The concept of universal accessibility also provides elements that are adaptable to facilitate any additional adaptations. Consequently, the scope of such adaptations will be much smaller than in a conventionally-designed housing unit.

Universally accessible housing is not meant just for persons with disabilities. It is perfectly suited to the entire population [4], while making it easier for some persons to function.

Designing a universally accessible project consists of arranging the interior and exterior common areas and the dwelling units so that any occupant or visitor can access them. They are easy to enter and move around in, easy to use and feel secure.

The main considerations for enhancing accessibility through increased building and dwelling unit flexiblibilty include:

- Site and Circulation
- Dwelling Unit Layout
- Additional Unit Features

[4] Universal Accessibility Performance Criteria, Société Logique Inc., CMHC (1994).

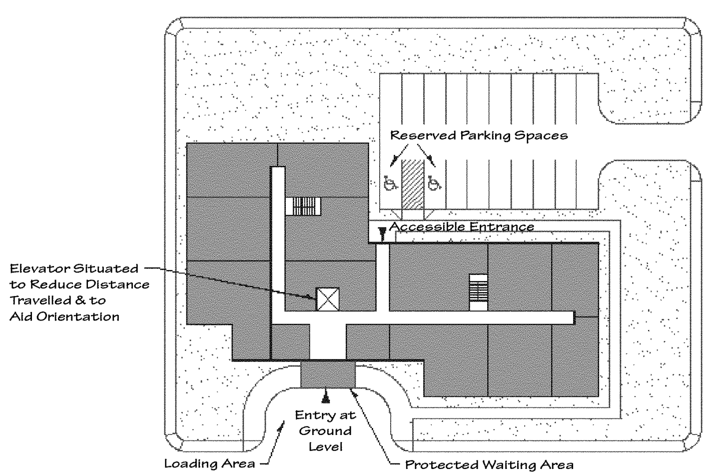
DESIGN CONSIDERATIONS

Site and Circulation

The National Building Code as well as provincial and municipal construction regulations contain barrier-free design requirements for common areas in residential buildings.

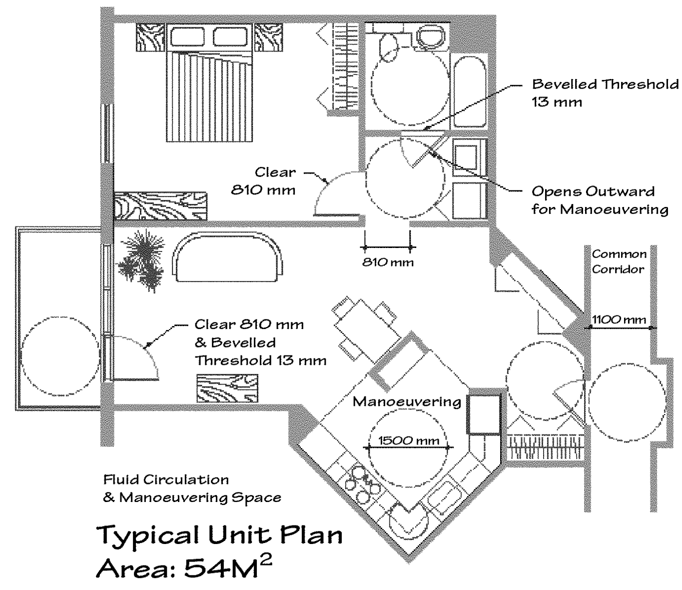
For better accessibility, some additional general building design elements should be considered.

Site & Circulation

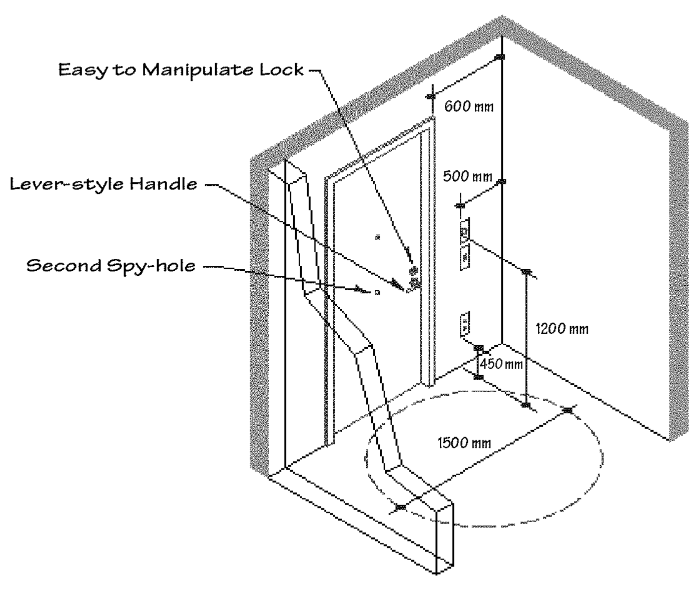


Site & Circulation

Typical Unit Plan
Area: $54M^2$



Entrance into Suite/Dwelling



Where possible, the siting of the building should allow for an accessible ground-level main entrance, without stairs or access ramp. The main entrance should be clearly visible from the street and have a protected waiting area, some benches and a drop-off lane. The exterior parking should include some spaces reserved for residents and visitors with disabilities. There should be a barrier-free pathway from the parking area to an accessible building entrance to the building.

Inside, the layout of the building and the location of the elevators should be defined so as to facilitate orientation and minimise the distances to the dwellings.

OTHER ELEMENTS

Fire Alarms

In the event of a fire, to ensure greater safety for persons with a hearing impairment, stroboscopic lights, linked to the building's general fire alarm system, should be installed in the corridors and common areas. In addition, each unit should have an outlet for a stroboscopic light or other alarm relay system which would be supplied and installed, if necessary, by the resident.

Aids for Visually Impaired

To facilitate orientation for people with a visual impairment, Braille and tactile signs should be installed in the elevators and stairwells on each floor, as well as a voice synthesis system in the elevators to announce the floor stops.

Stairwells and Stairways

To help elderly persons or those with mobility or agility impairment use stairs safely, continuous handrails on both sides are required. The risers should be closed and the steps covered with a non-skid surface. All flights of stairs between floors should be straight, with no angled steps. It is important to have adequate lighting in the stairwells.

Parking Areas

Where there is indoor parking, adequately large reserved spaces should be located near the elevators, to reduce the travelling distance and thereby increase resident safety. The pathway leading to the elevators should be barrier-free, with care taken around changes in levels and the force required to open doors. To allow adapted minivans to enter, the indoor parking should have a clearance of 2,300 mm.

Dwelling Unit Layout

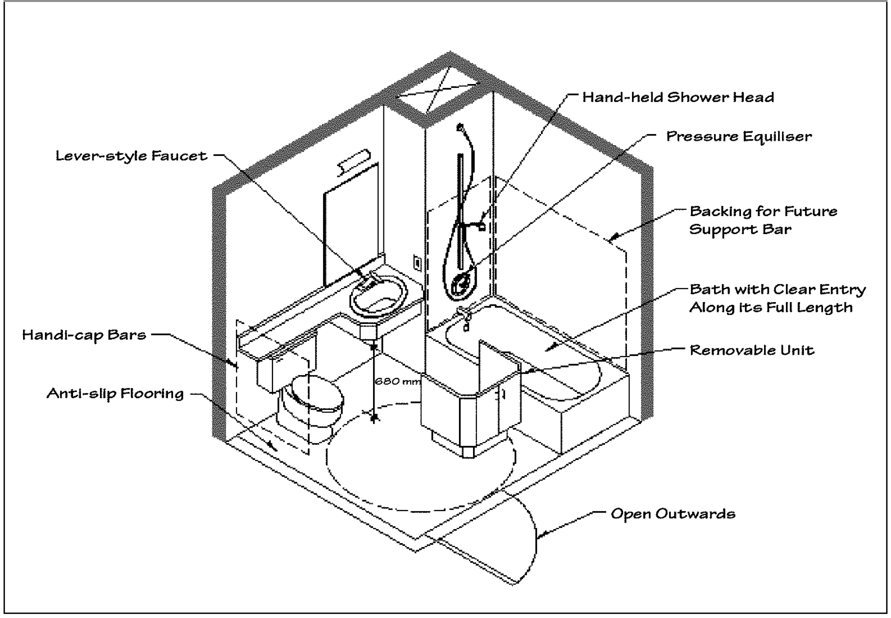
Building regulations contain very few requirements regarding the accessibility of housing units. To obtain good performance, designers must pay special attention to details. Two broad principles provide the required flexibility within the units.

1. Circulation should be unobstructed: there should be sufficiently wide hallways and doors (810 mm opening clearance), flat or beveled thresholds, and no changes in the level of the floor surface.

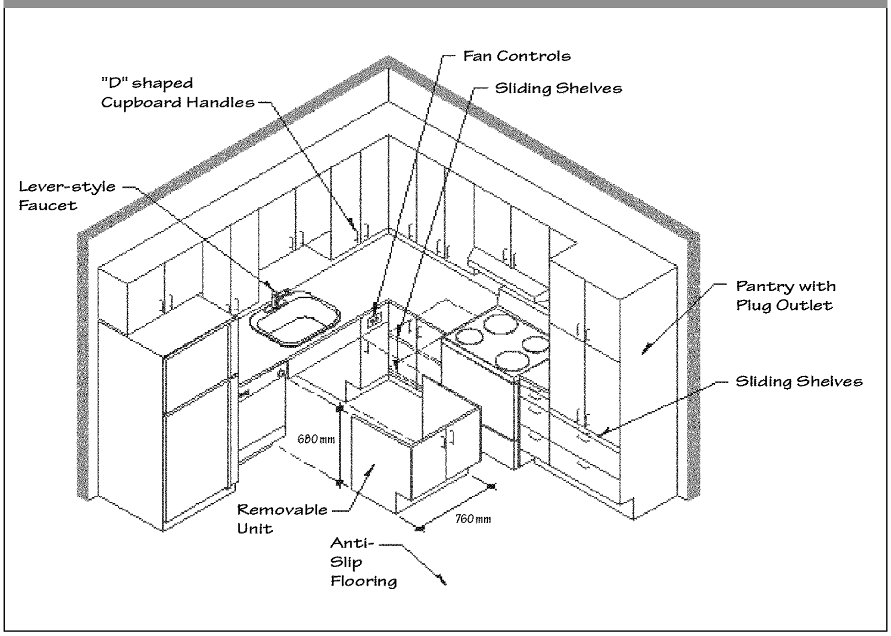
2. Using facilities and using equipment should be made easier with manoeuvering areas in strategic locations. Manoeuvering areas of 1,500 mm in diameter should be provided at the entrance, in the bathroom, in the kitchen, on the balcony and in a storage room within the unit. Details can be developed to facilitate access to balconies as well. This is important since these areas can be used as safe refuge during fire.

These two principles offer basic accessibility within the unit by creating enough space to enable all client groups to move around freely. Developers applying these two principles will provide their clients with very flexible housing.

Bathroom



Kitchen



Balcony Areas

An accessible balcony is an important security feature. A beveled threshold (maximum 13mm high) is required, without disrupting the thermal separation, water run-off and air-tightness. This can be achieved by providing a 50 mm high raised infill to accommodate the sill height difference. The height of the guard-rail must then be adjusted in order to comply with code requirements.

Subsequent Adaptations

Some elements to facilitate subsequent adaptations can also be included:

- for possible installation of grab bars, plywood backing for nailing placed behind the tile around the toilet and the bath enclosure,
- for possible installation of a wall oven, a vertical kitchen cupboard with an appropriate electrical outlet,
- for possible sink and washbasin knee clearance, a removable cabinet module and off-centre drainage plumbing,
- for lowering the clothes rods in the closets, a two-tiered clothes rod support.

The universal access concept does not usually require any additional space, in spite of the necessary manoeuvring areas. In fact, by streamlining the arrangement of the spaces, it is possible to design universally accessible units with the same floor area as conventional units. However, this will certainly be easier to achieve in buildings with generous spaces than in those where unit sizes are limited.

A range of good quality products exist on the market that are efficient for accessibility, at prices comparable to conventional products. It is therefore possible to choose accessible products and materials, at no additional cost.

Additional Unit Features

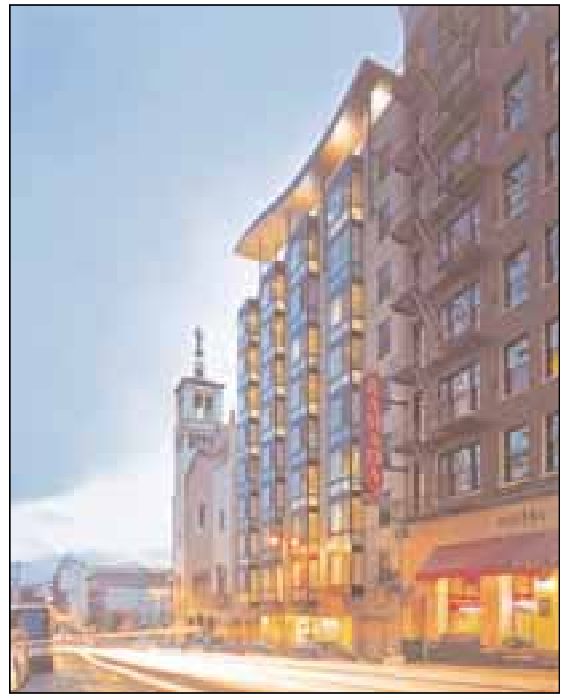
For developers who wish to further improve their housing, some additional elements can be integrated to facilitate use, such as:

- lever faucets and door handles,
- locks that can be easily handled with one hand,
- a second peephole in the door at a maximum height of 1,200 mm,
- closet doors with an opening clearance of 810 mm,
- switches, thermostats, electrical panel and outlets located between 450 and 1,200 mm from the floor, and more than 300 mm from wall corners,
- an electrical outlet near the bed, linked to a switch near the door,
- range hood controls on the counter-front,
- telephone–style shower,
- pressure equalizers for bath and shower fixtures,
- D-shaped cabinet and drawer handles,
- sliding shelves in the cupboards,
- non-skid, low-maintenance floor surfaces,
- window sills at a maximum of 750 mm from the floor,
- an intercom linked to the telephone.

Sources of Information

- *Adapting Low-rise Residential Buildings*, Sun Ridge Group, CMHC, PE0292
- *FlexHousing - Homes that Adapt to Life's Changes*, CMHC NHA #2020
- *FlexHousing the Professionals' Guide*, CMHC NHA # 2400
- *Design Options for Barrier-Free and Adaptable Housing*, Société Logique Inc. et al., CMHC, 1996.
- *Housing Choices for Canadians with Disabilities*, CMHC, 1992.
- *Universal Accessibility Performance Criteria*, Société Logique Inc., CMHC, 1994.
- *Building for a Lifetime: the Design and Construction of Fully Accessible Homes*, Wylde, Baron-Robbins, Clard, The Taunton Press, USA, 1994.
- *Barrier-Free Design: A National Standard of Canada*, CAN/CSA B-651-95, Canadian Standards Association, 1995.
- *Housing for Persons with Disabilities*, CMHC, 1996.
- *Housing for Elderly People: Design Guidelines*, CMHC, 1987.
- *Un logis bien pensé, j'y vis, j'y reste*, Société d'habitation du Québec, 1999.
- *La domotique*, Girardin P., Société d'habitation du Québec, 1994.
- *Les seuils d'accès facile aux balcons*, Pierre Richard,SCHL, 1999.

CASE STUDY



Award Winning Low-income High-Rise Breaks the Mould in San Francisco

CECIL WILLIAMS GLIDE COMMUNITY HOUSE

The Cecil Williams Glide Community House provides subsidized transitional housing that meets the needs of low-income "at-risk" individuals who are formerly homeless, living with HIV/AIDS, or recovering from addiction. The target population includes both families and individuals. The building designed by Michael Willis Architects on a modest $10,000,000 budget. The architecture counters the image of low-income high-rise housing. The facade, with simple geometry and clean lines, integrates easily with its surrounding downtown context. It is constructed of concrete, steel and post-tensioned slabs. The structure is clad in an exterior insulation and finish system (EIFS) with durable limestone at the street level. It features unusual details for low-income housing, like the tiled donor-wall in the lobby and a rooftop pavillion complete with glass-art windscreens. The project received the 1999 Award for Exellence in Architecture from the National Organization of Minority Architects and the 1999 Builder's Choice Grand Award from Builder Magazine.

THE INNOVATIONS

The Glide House is a 9-storey, 52-unit building in downtown San Francisco. It offers a mix of studios, one-, two- and three-bedroom units, on-site administrative and social services, an infant care centre, a multi-purpose room and informal gathering areas, including a rooftop pavillion. Innovatively designed, the L-shaped building wraps around a central courtyard maximizing light penetration into the building.

CMHC SCHL

HOME TO CANADIANS

Canada

The public areas in the building are fully-accessible to wheelchairs and 4 of the units are designed specifically for wheelchair occupants. The other units have been built to be adaptable to accommodate wheelchairs. All the washrooms are wheelchair accessible. Other accessible design features include lever-style door handles, low window sills, sliding cupboard doors, front-accessible controls on stoves and clothes wahing/drying machines and fully accessible bathing fixtures (hinged pull-down seat, lever-style showerheads, grab bars, etc.).

Project Info

Location:	San Fancisco, USA
Architect:	Michael Willis, Architects
Gross Floor Area:	4700 M^2
Number of Dwellings:	52 units
Completion Date:	1999
Further Information:	Cecil Williams-GLIDE Community House 333 Taylor St. San Francisco USA 94012 Phone (415) 674-6100 http://www.glide.org http://www.mwarchitects.com

CASE STUDY

Blair Court an Example of Sustainable, Universal Housing

BLAIR COURT

Blair Court is a mixed-use residential/commercial building that was designed in 1990 as a home to seniors, people with disabilities, single parent families and lower income groups. The project was sponsored by the Province of British Columbia and developed jointly by the Vancouver Resource Society (VRS) and a private landowner. In 1992, the Canada Mortgage and Housing Corporation awarded the project the CMHC Housing Award for Financing and Tenure. A redesign of its courtyards and open spaces in 1998 improved the livability and accessibility of the original design.

While in the early 1970's the choices open to people with disabilities in B.C. were limited to either living in an institutional setting, a group home or with a 24-hour attendant, VRS wanted to promote the integration and independent lifestyles for those with disabilities. The Blair Court project sought to create a universally accessible building, using subtle design modifications, that would support a mix of residents, and encourage a neighbourly atmosphere.

THE INNOVATIONS

Of the 39 suites in Blair Court, approximately 20 are wheelchair accessible, 10 are wheelchair adaptable and the remaining 9 are of standard design. The building incorporated a number of barrier-free design features, including wider door widths, levered door handles, and horizontal floor panels in the elevators. The suites are compact, efficient, and roomy in the areas needed to be so. By placing the commercial space at grade, and locating the residential units on the upper floors, the designers also created a safe, secure, open courtyard oriented to the south that residents can access from their homes.

The courtyard's landscape features were also designed with accessibility in mind. Planter heights and widths were reconfigured for wheelchair access (530 mm above pavers and 762 mm respectively), walls were given shelf-like capping to permit the placement of potted plants, and hosebibs with more readily accessible lever handles were installed.

Project Info

Location:	Vancouver, Canada
Architect:	Neale Staniskis Doll Adams
Number of Dwellings:	39 units
Completion Date:	1990
Further Information:	Vancouver Resource Society 310-2150 West Broadway Vancouver, BC Canada V6K 4L9 Phone (604) 731-1020

CMHC SCHL

HOME TO CANADIANS

Canada

In This Section

Liquid Waste Systems
- integration at building and lot scale
- integration at block and neighbourhood scale
- integration with other infrastructure systems

Potable Water Systems
- same as above

Energy Systems
- same as above

Solid Waste Systems
- same as above

Transportation and Communication Systems
- same as above

Management and and Financing Strategies
- total cost assessment
- an expanded integrated design process
- participation in public/private partnerships
- micro-utilities
- risk management
- an environmental management framework
- indicators of performance
- green building and development guidelines
- increased use of energy and material flow models
- rules of thumb for selecting optimum scale and location

Case Studies

World-wide efforts are improving urban sustainability by providing an integrated infrastructure which combines the needs of building, site, neighbourhood and city. The challenge is no longer simply to “hook-up” to the civil infrastructure, and service your site via grids connected to remote facilities. Instead healthy high-rises can benefit from exploring a wide range of opportunities for green on-site infrastructure.

On-site infrastructure such as waste water treatment or energy generation requires that designers and planners adopt smaller scale urban systems which are distributed more widely. They can be located closer to and within buildings, integrated with elements of buildings, or with other infrastructure systems. Large grids and remote treatment and generation facilities can give way to distributed systems, organized into a smaller hierarchy.

Green infrastructure incorporates appropriate technologies and green materials that closely match user needs to the resource and system . From this perspective, natural and low-tech products and systems are applied before complex or resource-intensive solutions. The highest quality water and energy is always reserved for the most demanding end uses. On-site and renewable resources are used wherever possible, and then supplemented by larger scale infrastructure as necessary. Green infrastructure is actually ‘hybrid infrastructure’ that is more resource efficient, adaptable and sustainable.

This section of the Healthy High-Rise Guide provides an overview of some of the concepts and technologies that can be used to incorporate Green infrastructure planning into high-rise development. Key design principles for best practices and innovative technologies are reviewed for each type of infrastructure.

Some of the on-site technologies for servicing high-rise buildings have already been described in previous sections dealing with storm water management, energy supply systems, and solid waste. This section will add descriptions of on-site systems for liquid waste and transportation systems. In addition, examples of how these systems can service clusters of high-rise buildings, at the scale of housing, block and neighbourhood.

TRANSFORMING THE CITY

Green infrastructure revolutionizes the scope of design issues for buildings and and urban systems. This change is analogous to the computer revolution, where a large, centralized, expensive and single purpose ‘main frame’ infrastructure has been almost completely replaced by a diverse network of on-site systems.

At the block and neighbourhood scale, the distribution nodes will include clustered, self-reliant, mixed developments of housing, commercial space and industry. Every large housing development may be seen simultaneously an opportunity for a water factory, an electrical generating system, a solid waste management system, a storm water management system, a communications node, an agricultural facility, an employment centre and so on.

As a consequence, the design process is becoming more challenging and interdisciplinary. Increasingly we see a blurring of the traditional boundaries that separate one type of ‘building’ from another, and buildings from their civil infrastructure. Large distribution grids and remote treatment and generation facilities are giving way to a network of ‘on-site’ infrastructure systems, with shared elements.

More mixed-use land use and building types can complement the on-site infrastructure systems, by evening-out the demand for services, and creating opportunities for re-use and synergy. The traditional parceling of land with the isolation of industry and infrastructure will give way to a multi-layered approach. We will literally wrap our homes and offices around the industrial and infrastructure systems, as they become a shared source of warmth, water, food and diverse employment.

Such a transformation will be difficult given the current norms for private property, and existing fee structures and planning policies for municipal and regional utilities. However on-site, sustainable integration becomes increasingly more possible as utilities are deregulated and as capital projects are delivered through public private partnerships and performance-based contracts.

‘Micro’ utility servicing equipment is now available for on-site water treatment, water recycling, cogeneration and heat transfer. Innovative storage systems can be used to enhance renewable energy supplies. Artificial intelligence can support more inexpensive safety systems and can help to control flows of resources between housing developments and grids. New financial resources will be directed at protecting the capacity of the local ecosystems, and reducing greenhouse gas emissions.

All these innovations are opening the door to a more flexible, diverse and integrated approach to providing urban services for high-rise residential buildings.

LIQUID WASTE SYSTEMS

THE ISSUES

Developers and communities in Canada are adopting integrated, ecological approaches to wastewater treatment and water reclamation. A motivation is the general public disdain for reliance upon chemical processes for wastewater treatment. The success of many constructed wetlands is another driver. Public officials in Canada are starting to recognise the benefits of ecologically engineered systems which are widely accepted in Europe.

Green wastewater infrastructure is superior in removing VOCs, hydrocarbons, nutrients, herbicides and pesticides, in addition to pathogens. They don't simply manage the waste, but instead transform the resource into reclaimed water, soils, nutrients, CO_2 and biodiversity. At a local scale, it means the re-integration of the wasted resource while minimising distribution costs and land use.

DESIGN CONSIDERATIONS

Integration at Building and Lot Scale

Flow reduction at source

The first step is to reduce the flow of wastewater leaving the building. Storm water is directed into open drainage systems. Water use indoors is minimised through use of water-conserving fixtures.

On-site composting

Waterless composting toilets can cope with all that sewage. Ventilated aerobic composting system reduce the waste volume by 90% and removes pathogens. The humus-like soil amendment which results is rich in nitrogen and other useful elements. Returning it to the earth restores depleted soil conditions. Fluid waste is treated in small odourless reed patches next to building. Substantial amounts of water are saved relative to conventional flush toilets.

On-site primary treatment

Primary treatment is achievable at the building scale. Watertight concrete septic tanks next to the foundations of apartment buildings can become the primary treatment stage for all wastewater. The advantage of having this system next to the building is that it then becomes possible to provide very low cost, flexible and advanced secondary treatment at the neighbourhood scale. Basically a submersible pump is used to decant the fluid in each septic tank, and then send the fluid through small-diameter PVC pipes to a neighbourhood scale digester.

Integration at Block and Neighbourhood Scale

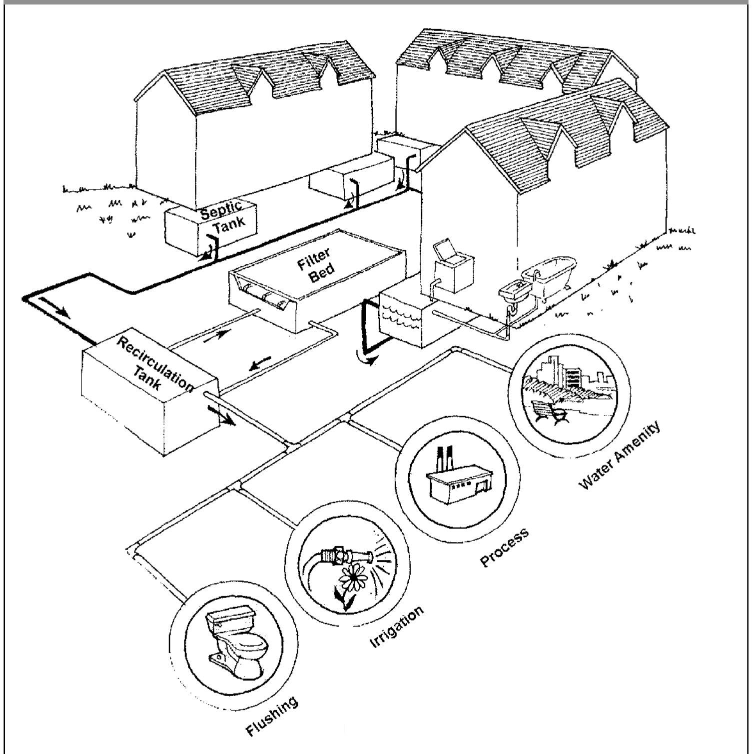
Advanced Secondary Treatment using Aggregate or Membrane Filtration

These systems can be dedicated to serve large multi-unit residential buildings, or clusters, or even small towns. Essentially a piped system transfers effluent from septic tanks to a central location. A recirculation pump repeatedly sprays the effluent over a subterranean gravel or membrane filter, which drains back to the tank. After 2 or 3 days of periodic spraying, the anaerobic digestion is complete, and the effluent is colourless and odourless (although still high in nitrogen). This treated effluent is suitable for use in augmenting and flushing ponds and rivers, and for use in irrigation, in non-potable water systems, and in industrial processes. The filter bed can occupy a small area within the cluster of buildings, where it can serve as a multi-purpose outdoor courtyard for passive recreation activities.

Solar Aquatic Sewage Treatment Systems

Solar Aquatics is engineered technology that replicates the natural purifying processes of fresh water streams, meadows and wetlands. Wastewater flows through a series of clear-sided tanks located in greenhouses, and then through engineered streams and marshes where contaminants are metabolized or bound up. Bacteria, algae, plants and aquatic animals are

Example of Integrated Liquid Waste System Using On-site Advanced Secondary Treatment



all part of the treatment system. Solar Aquatics technology can be used to treat sewage flows from 20,000-500,000 gallons per day. The treatment has been applied to sewage, septage, boat waste and ice cream processing waste.

Biofiltration Marshes

Biofiltration swales and marshes will protect sites from offsite contaminated waters. These swales also provide narrow wildlife corridors and erosion control on steeper sites.

Integration with other Infrastructure Systems

Heat from Sewage

Energy can be extracted from discharged water by means of efficient water-to-water heat pumps in a decentralised water reclamation system. The captured heat can then used to heat water for space conditioning of greenhouses and other buildings.

Reclaimed Water

Tertiary treated sewage can be classified and sold as reclaimed water when taken through a number of additional and prudent steps (UV disinfection, carbon and membrane filtration). Reclaimed water can also be used for irrigation of golf courses, parks and grounds, toilet flushing, construction uses such as aggregate washing, concrete manufacture, and wetland or stream augmentation. Permaculture landscaping can help to convert water reclamation facilities into productive and diverse gardening systems, converting the nutrients into useful biomass and biodiversity

Methane capture

Methane produced in the decomposition of municipal organic wastes and sewage can be piped to buildings or to a cogeneration plant for electrical generation and heat. Some sewage treatment plants are powered and heated by methane from this source.

Bioponics

Bioponics, the integration of aquaculture and hydroponics are usually housed in a greenhouse, and integrated with greenhouse-based water reclamation systems.

Humus

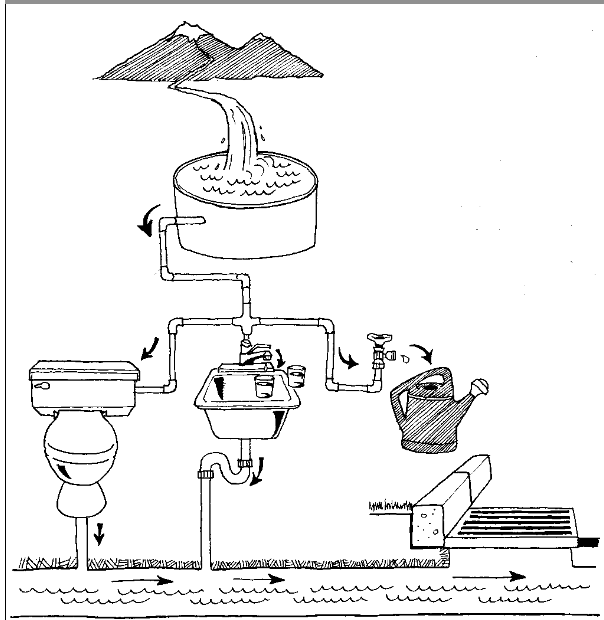
Sludge collected from sewage treatment plants is used as an organic additive to support storm water filtration systems and other types of urban landscaping, agriculture and land restoration.

POTABLE WATER SYSTEMS

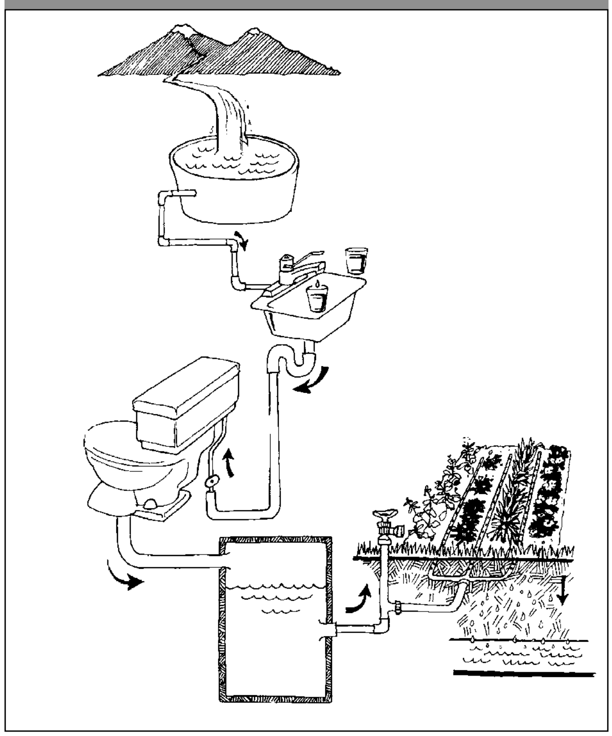
THE ISSUES

Green infrastructure for potable water begins with matching the quality of water to the end use, and then cascading the wastewater flows through a series of lower quality uses. High quality potable water is best used only for top-grade drinking water, and by the food and beverage industries. Other functions, such as toilet flushing, landscape irrigation, clothes washing, and so on, can be fulfilled using non-potable water such as greywater. Demand management is especially suitable for potable water systems. Designers and planners need to optimise investments required for increased water supply, with more efficient end-use technologies (low-flow fixtures, water-efficient appliances, drought resistant gardening, etc.). Load management is a third strategy, and may include on-site storage of potable water, as well as behaviour changes (through meters, rate structures, water bans and so on). Through a combination of these strategies, multi-residential development can improve the quality of water services, lower costs for occupants, and allow the community as a whole to manage water resources sustainably.

Inapproriate Water Use, circa 2000



Approriate Water Use, circa 2050



DESIGN CONSIDERATIONS

Integration at Building and Lot Scale

Cisterns

Cisterns can be used at the building site to store water captured from roads and hard surfaces to provide occupants with a source of water for toilet flushing, irrigation, and after filtration - drinking and washing.

Greywater

Grey water systems within buildings help to “cascade” water flows from bathtubs, showers, bathroom washbasins, and water from clothes washing machines laundry tubs into toilet flushing and garden irrigation. Two-pipe systems provide buildings with the means for using reclaimed water. The reclaimed water may be generated at the neighbourhood scale from wastewater, and returned to buildings in a separate piping system for all non-potable uses. An increasing number of cities are adopting two-pipe systems for all new buildings (e.g. commercial buildings in San Diego, all buildings in Hong Kong).

Integration at the Block and Neighbourhood Scale

Water Reclamation

Reclaimed water is wastewater that has been treated to meet or exceed drinking water standards before being reintroduced into the raw water supply. While this type of system is usually uneconomic at the building scale, it may be worth considering for a number of high-rise residential buildings in a location where water is scarce.

Integration with other Infrastructure Systems

Potable water

Potable water can be used as a coolant to provide supplementary air conditioning for buildings. Potable water can also be used as a source of heat, if heat pumps are submersed in the wells, reservoirs or storage tanks.

Water reservoirs

Reservoirs with flow control dams can be equipped with micro hydro generators.

Windmills

Windmills can be used to assist with pumping water from the ground, and overland. The windmills provide electricity generation during times when pumping is not required.

ENERGY SYSTEMS

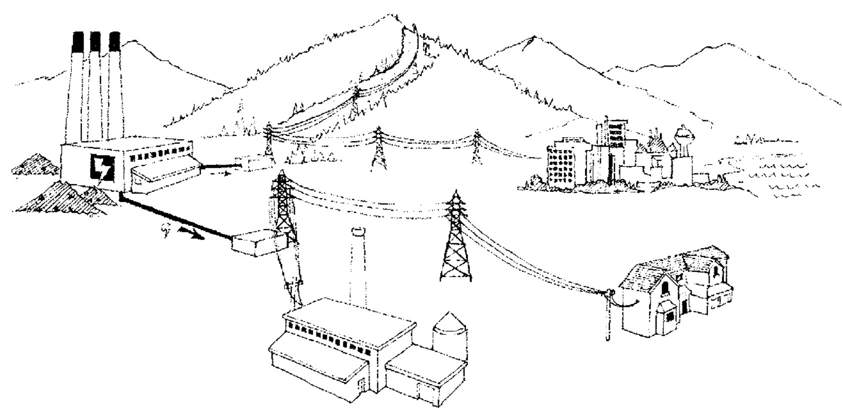
THE ISSUES

Green energy infrastructure relies on low-impact renewable sources. These resources vary as to location, and include wind, sunshine, geothermal, run-of-river hydro, tidal and wave power, wood waste, landfill gas and biogas, agricultural, forestry and animal wastes, and lake and ocean cooling.

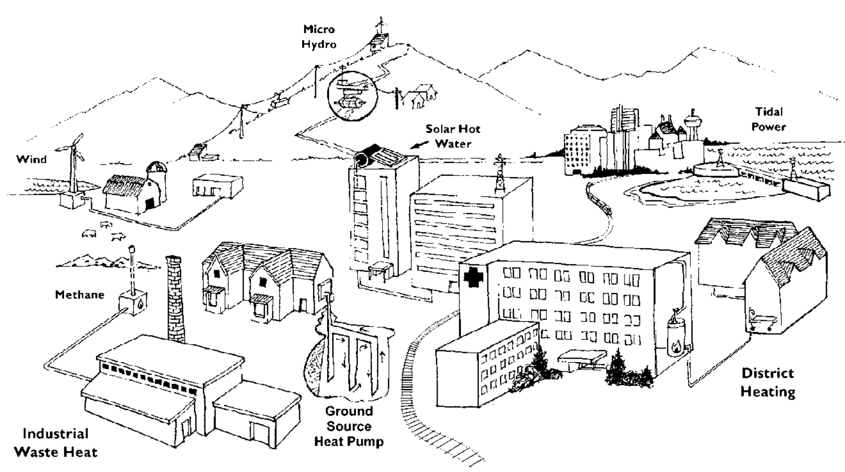
Generally the use of renewable resources benefits from existing energy grids. The grid absorbs peak demands, and stores energy when renewable sources are surplus.

Green energy infrastructure should be an integrated and planned, connecting all activities withinan urban area. Municipalities in northern Europe show how to integrate energy into urban plans not just focusing on energy conservation and efficiency in isolation.
A planned system better ensures a mix of energy supply, and more effective matching of energy-quality to end-use. Buildings and industries are both suppliers and consumers of heat and power. Like water, energy flows are engineered to cascade from the highest to lowest quality uses. Distribution losses and transformation losses are minimised by on-site generation. The urban form and building placements optimise use of on-site forces like sunshine, breezes, hydro and heat generating activities. And finally, energy resources are extracted from all other resource flows within the city, like water and solid waste.

As the energy marketplace is deregulated and becomes diverse, all cites will face new choices. They will need to select their energy partners and mix of energy sources, and how energy commodities will be converted, stored and transferred. Such choices can radically alter the energy efficiency of the entire city. The City of Toronto converts raw energy resources like coal and uranium into usable energy at an estimated efficiency of 50%, while the City of Helsinki, which uses waste heat from energy generation to



Centralized Energy System, circa 2000



Distributed Energy System, circa 2050

heat 91% of the housing, achieves an efficiency of 68%.(1) In future cities will use energy systems plans as strategies to enhance the competitiveness and resiliency of the local economy, and to achieve social goals for housing affordability and a cleaner air shed.

DESIGN CONSIDERATIONS

Integration at the Building and Lot Scale

Please refer to Alternative Energy Supply Systems in Section 2: ENHANCING ENERGY PERFORMANCE.

Integration at the Block and Neighbourhood Scale

Energy Storage Facilities

Longterm storage can be provided at the neighbourhood scale. For example, a large underground reservoir heated by solar water heaters mounted on clustered buildings.. In this way, summer sunshine is stored, and can contribute from 50 % to 70 % of the overall heating demand in the cluster. The storage volume can be increased in stages to match the growth of housing, using earth ducts with high mass.

Cluster Systems for Space Heating and Cooling

Co-generation at local scale can involve micro-generators sized to match the base heating load for the development. In this way all the waste heat from electricity generation can be used locally, greatly increasing the overall efficiency. Supplemental electricity and heating needs can then be met by grid sharing, or by a combination of other on-site technologies.

District Heating

District heating may use a single boiler complex to supply heat for space and water heating throughout the neighbourhood. Loops of small-diameter, well-insulated hot water pipes efficiently transfer the heat to buildings as far as away 7 kilometres. The boiler complex can be located in a commercial or institutional centre (hospital, mall) or a nearby industry. These buildings require large, well-managed systems and can support the maintenance of the system. The energy resource mix and emission controls can be controlled at a single location. Each building on the district heating system benefits by lower floor space requirements and higher quality service.

Renewable Resources

Renewable resources are collected from the regional inventory, and distributed to the building clusters as appropriate. Local sources may include:

- Methane from landfill and composters,
- Turbines in storm and water distribution systems,
- Micro-hydro; and
- Wind turbines.

Integration with other Infrastructure Systems

Incineration

Incineration of solid wastes is sometimes a source of energy supply, if no economic options exist for recycling of some plastics and organics.

Methane Recovery

Methane is a renewable energy source derived from liquid waste digesters and landfills

Heat Pumps

Heat pumps can draw useful heat from sewage flows and water reservoirs.

Solar Power

Photovoltaic arrays can be mounted along the south-facing walls of highway barriers, and other accessible, low-impact locations;

Mini-turbines

Mini-turbine generators can be mounted in water supply and storm water systems, and at outlets of large water reservoirs.

[1] The Potential for District Energy in Metro Toronto, Metro Toronto Works Dept., CANMET NRCan, Ontario Hydro, 1995.

SOLID WASTE SYSTEMS

THE ISSUES

Green infrastructure systems for solid waste manage material resources, and eliminating waste altogether. A green system thus requires Coordination is required among those involved in the material supply chain, to ensure that materials are designed, packaged, transported, and assembled in a manner that minimises material use and that facilitates re-use and recycling. Toxic products are avoided, as are superfluous materials for decorative finishing. In ideal situations, manufacturers become service providers, and directly repossess the materials and goods when it is time to refit or recycle.

For high-rise developments, the solid waste infrastructure must be considered during the land clearing, construction and demolition stages, and on-going operating systems for the occupied site.

Land development must be consciously planned to preserve existing vegetation wherever possible, and to compost the remaining organic materials on-site. Road and site excavation tries to equalize the cut and fill. Building designs avoid wasteful practices and incorporate materials that are durable and easy to recycle. Construction and demolition practices plan for waste management.

Once the site is occupied, organic materials must be kept nearby (instead of being trucked large distances to landfills) and used to enrich the landscape and to enhance the performance of other infrastructure systems. The nodes for collecting, separating, storing and re-using wastes need to be carefully integrated into buildings, block and neighbourhood planning, so as to ensure accessibility and social acceptability.

By following these broad waste management strategies, a high-rise development can become a key element in the urban waste management infrastructure.

DESIGN CONSIDERATIONS

Integration at Building and Lot Scale

Please refer to Solid Waste in Section 4. ENVIRONMENTAL PERFORMANCE.

Integration at Block and Neighbourhood Scale

Reuse It and Recycling Depots

Larger residential developments can benefit from depots for dropping off waste products. Such depots can often be integrated into the other community facilities (school, day care, recreational park, corner store) and designed to enhance community interaction as residents regularly deposit bottle returns, recycling materials, and materials suitable for re-use. Depots can be combined with high-rate composting facilities as well.

Composting

Composting on a block or neighbourhood scale uses a variety of systems:

- Windrows of organic waste typically require a few acres of land. Raw organic materials such as yard trimmings are laid out in rows and turned periodically. After they are degraded by microbial activity the end product is relatively stable, reduced in quantity and free of offensive odours. The humus-like material can be recycled as a soil amendment and fertiliser substitute.
- Aerobic digesters use thermophilic (heat responsive) microbes to process organic waste over a 72-hour period with zero harmful environmental discharge. The digested waste is converted into organic fertiliser products with high market value in both liquid and dry-pellet form.
- In-vessel composters are large containers that process organic wastes over a two-week period. A hopper at one end is used to load the vessel. An auger automatically mixes and

turns the waste materials. A fan is used to ensure adequate supplies of oxygen. Additional materials may the added to the vessel to ensure that the mix of organics is suitable for efficient composting. The end product is humus that can be used in manufacturing soils, and landscaping.

- Vermiculture systems use worms to rapidly digest and sanitize organic wastes, including kitchen waste and shredded cardboard. More hungry worms and high quality organic fertiliser are produced.
- Enzyme-based composting systems are proprietary machines that accelerate the decomposition over several.
- Transfer and Sorting Stations: Neighbourhoods can accept small stations that further separate the waste and compact the material before shipping to users. Local stations increase work opportunities and industry customers can locate close by further reducing transportation requirements.

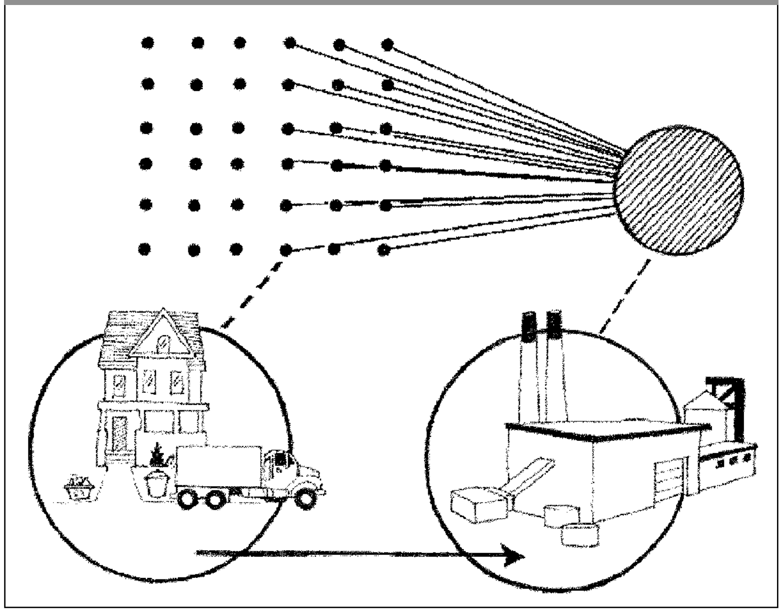
Integration with Other Infrastructure Systems

Organic waste can be composted and incorporated as an absorptive soil additive in an open storm water management system.

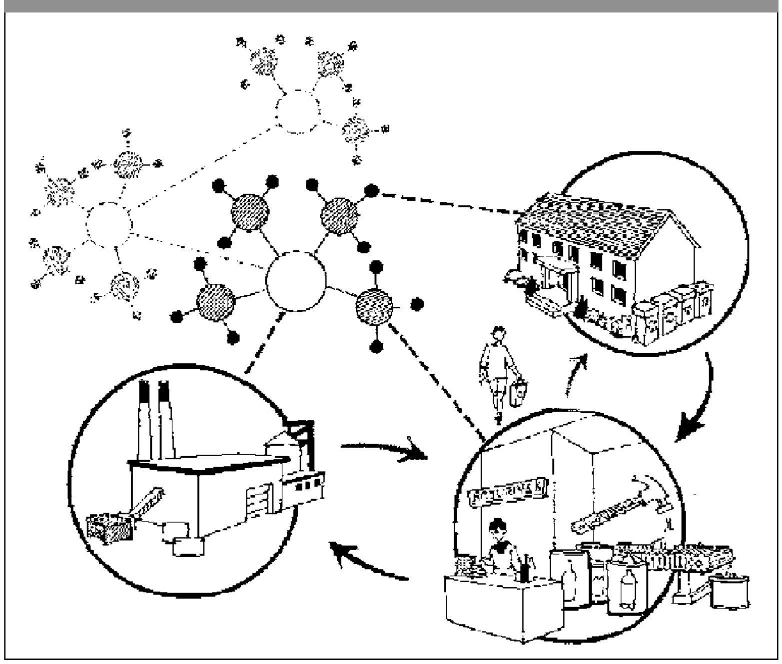
Local, renewable energy can include the methane generated from composting solid wastes, and from incineration.

Organic waste materials can also be top dressed on landscaped areas, and used to minimise irrigation water supply requirements.

Remote & Isolated Solid Waste Management, circa 2000



Clustered Solid Waste Management, circa 2050



Solid waste management depots in the neighbourhood can also be used to reduce requirements for roads and to support lifestyles that include neighbourhood shopping and walking.

TRANSPORTATION & COMMUNICATION SYSTEMS

THE ISSUES

Transportation as a service needs to be redefined. The object is accessibility, not moving people. Hence the green infrastructure for transportation may actually consist of land use planning that locates jobs close to or inside housing, and that ensures clusters of services like shops, schools and parks are within walkable distances from most residences. The cluster structure is a key design element. The connections between clusters of varying scales should also provide resource-efficient transport, include safe, dependable and convenient transit, high quality amenities for non-vehicular transport (bicycles and walking) and amenities for non-fuel powered vehicles. Connections include communications technologies that provide access without actually moving people and materials.

Electricity generated from renewable resources is especially well suited for light rail systems and trolleys. Longer distances between major nodes are best suited for mass transit. European cities show how to lure people out of their single occupancy vehicles when dense mixed-use neighbourhoods are combined with extremely clean, convenient and affordable transit. By discouraging the use of private vehicles inside cities, areas covered by large road surfaces can become amenities that improve the quality and scope of living within cities. . Reduced smog is another major contribution.

DESIGN CONSIDERATIONS

Integration at Building and Lot Scale

Complementary Building Occupancies

Locating several complementary occupancies within a project often eliminates the need for many automobile trips., Occupants can walk or use lower-impact biking and transit. Parking spaces in mixed-use buildings and developments can often be shared between occupancies with differing schedules, reducing the area of impervious parking pavement, stormwater peak flows and pollution.

Pedestrian and Bicycle Amenities

Making streets safer and more attractive to pedestrians will reduce car use. Bicycle facilities at destinations and safe, continuous bicycle paths are also needed. Building designs can provide secure bicycle parking, showers and changing facilities. Building designs can also improve the comfort and safety of pedestrians with appropriately scaled and detailed facades, and with street views for building occupants. Provided with a choice of sun or shade, pedestrians are more likely to use outdoor spaces. An attractive street generates places for social interaction, increasing the vitality of the neighbourhood and providing better commercial opportunities.

Live-work spaces

Building designs can include swing spaces that can be easily converted into home offices with soundproof walls, direct access to exterior, and suitable wiring, cable connections and lighting. Live-work spaces provide options both for tele-workers and the self-employed.

Transit Access

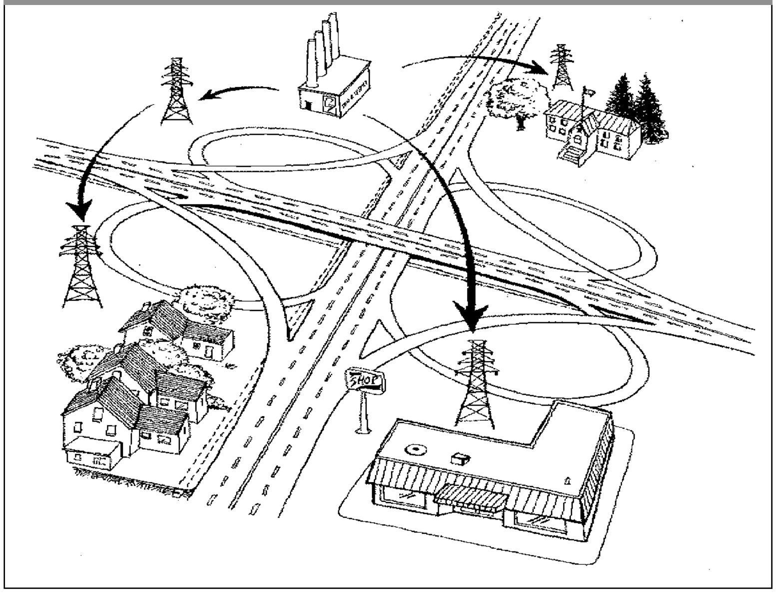
Design details make a difference in comfort, convenience and accessibility to transit users. A clear line of sight to transit stops is ideal, with paths that avoid crossing traffic, and with weather protected shelters .

Integration at Block and Neighbourhood Scale

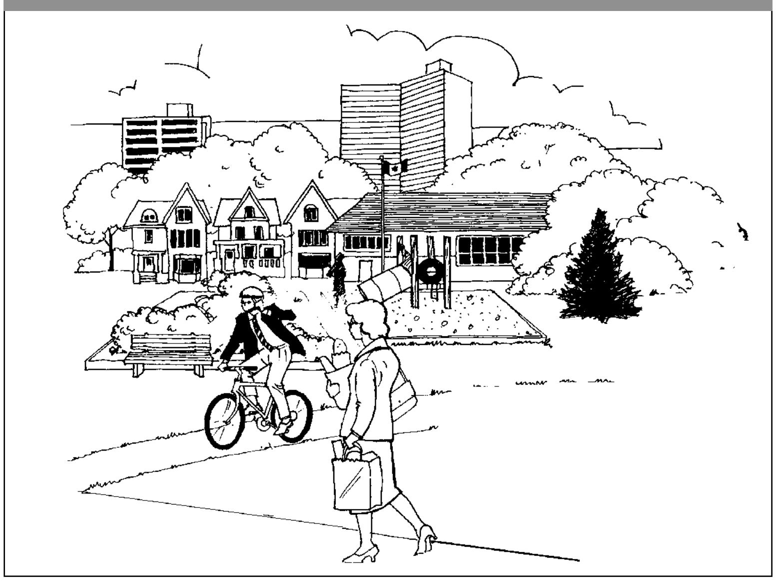
Network of Pathways

Pedestrian and bicycle paths encourage an alternative to satisfy basic needs. Paths should connect residential areas to amenities as well as to neighbouring communities. A fine-grained network will include local connections within blocks that in turn connect with a neghbourhood system as well as the larger citywide network.

Not Service Oriented, Circa 2000



Dense, Mixed-Use Urban Villages with Network of Paths, 2050



Integration with Other Infrastructure Systems

Transportation routes can serve as integrated utilidors with pipes for heating, cooling, methane, hydrogen, communications and so on.

Walk and cycle paths can also function as filtration strips for storm water.

Walkable communities can use central locations to provide residents with easy access to material recycling and reuse depots.

Run-off can be reduced and treated on-site if road surfaces are minimised and if the remaining other areas are designed to be permeable.

Natural landscaping can also be integrated into car parking areas to the same effect. Shading of parking areas and building surfaces reduces the amount of solar radiation reaching them, which can in turn significantly lower energy demand for building cooling.

MANAGEMENT AND FINANCING

THE ISSUES

Integrated multi-functional infrastructure projects are by their nature a difficult sell. Many of the benefits are indirect, the risks appear to be substantial, and the number of stakeholders can be overwhelming. Extremely challenging obstacles must be addressed in order to minimise the costs of on-site systems and to receive both co-operation and compensation from local governments and utilities. Some of the more common obstacles include:

Formula Thinking
System designers have been trained to use slice-and-dice, component-based design methods that are simple, clear, and wrong, because they optimise components in isolation and neglect the systems of which they are a part. They focus on single rather than multiple benefits.

Fragmentation of Authority
Historically, the development of each type of infrastructure occurred at different times, largely in isolation. This has left us with agencies, industries, and monopolies organised around specialised mandates, and with compartmentalised worldviews.

Fragmentation of Ecologies
It is especially hard to protect and enhance the ecological integrity of an area if other decision-makers erode the benefits. For example, reducing pollution on your site can be pointless if another development, upstream then chooses to pollute the air or water at much higher levels.

Sunk Investments
The very substantial capital outlays dedicated to existing infrastructure can eliminate the potential for cost savings from green infrastructure. Sometimes property taxes are already predicated on paying for larger, centralized systems, and thus anyone who invests more money to reduce reliance upon such systems, ends up paying twice.

Inflexible Policies
Many types of existing policies prevent holistic thinking and on-site applications. They often only recognise one way of achieving results (the status quo) and thus frustrate innovation within the market place. Health and safety policies may not reflect new ecological technologies, and the relative importance of protecting environment. Land use policies may run completely counter to the concept of mixed use and municipal ecology.

Bundled Fees
Subsidies and fees are often structured in ways that are insensitive to variations in user loads and consumption rates. For example, development cost charges may be based entirely upon factors like zoning and floor area, despite the possibility that the design of greener buildings and on-site infrastructure may reduce or even eliminate the requirement for certain types of municipal infrastructure investments.

Larger Utilities Supporting Status Quo
Despite efforts at deregulation, it is still possible for large utilities to influence the market, and to under-price new initiatives that threaten their market base.

Lack of comprehensive cost/benefit models
Cost benefit modelling of infrastructure options cannot currently account for the potential benefits of integrated systems, since the models are not broad enough.

DESIGN CONSIDERATIONS

The many obstacles to green infrastructure emphasise the importance of adopting methods and tools that contribute to successful project management. Some especially useful strategies are outlined below.

Total Cost Assessment
Green infrastructure is a non-starter as long as developers apply conventional accounting

practices, that separate budgets into 'silos', and that reward false economies. An engineering study may indicate that the lowest cost option is to 'hook-up' to the hydro grid and ignore on-site energy. However from a 'total cost' perspective the savings may be false, since a micro-generator, operated by a micro-utility, could provide both heat and power, save the space and costs for individual heating plants in each building, offer the developer an on-going revenue stream, and offer the residents security against rising energy prices and grid failures. Typical 'cost/benefit' analysis usually fails to recognise the potential for green infrastructure. The solution is Total Cost Assessment (TCA), which expands the financial analysis to include a broader range of direct, indirect, contingent and less quantifiable costs.

TCA can be used to optimise the 'looping' of financial resources, - reallocating cost savings from one type of budget to another in order to finance the lower-cost integrated system. An example might be the evaluation of designs for a denser, mixed-use community. TCA indicates that residents in the denser community will make fewer car trips, and require smaller roads and fewer parking spaces; thus money and land can be taken from the transportation infrastructure budget and used instead to pay for amenities like parks and daycares in the denser, mixed-use development. Still more money can be taken from highway construction and upkeep budget, and used instead to subsidise live/work accommodation or to provide communication systems for co-ordinating tele-workers and transit. In a highly integrated development, it is necessary to create a "megafund" for redistributing money across all classes of infrastructure interventions.

Expanded Integrated Design Process

The best method for addressing opportunities for green infrastructure is to expand the Integrated Design Process (IDP). Right from the start it is useful to include on the team individuals knowledgeable about the opportunities and constraints of the urban infrastructure. Unfortunately the tendency in most projects is to focus initially on built form and land uses like open space and transportation routes. An assumption is made that infrastructure issues can be dealt with "later", once the basic concept plans are completed and approved. However the reality is many green infrastructure solutions are intimately related to land use and built form. Thus it is vital to consider the residential development and associated on-site infrastructure simultaneously, as part of an Integrated Design Process.

Participation in Public Private Partnerships

Municipal participation, in the form of public private partnerships (PPPs), can be an essential enabling strategy for the creation of more integrated and smaller scale infrastructure. While the municipalities' role in such partnerships may remain small, their involvement will commonly add a large measure of confidence to the project investors, and to the marketplace. With a lower perceived risk among the stakeholders, it becomes easier to find affordable financing.

Micro-utilities

Neighbourhood scale integration raises substantial difficulties in terms of ownership, liability and maintenance of infrastructure systems. Often this is the greatest obstacle to embracing green infrastructure. One solution is to facilitate the creation of small, community-based utilities that are capable of managing all aspects of shared infrastructure for the cluster. Everyone connected to a system is automatically a stakeholder having revenue incentives to use the system responsibly. Success of resource recovery approaches may require some guarantee of buyers for the products. Stakeholders have a built-in incentive to consume the products (trees, water, bedding plants, flowers, tropical plants, compost, materials,) from their "own" utility thereby supporting its revenues and their dividends.
and emissions associated with development plans. Essentially such a model will simulate the interaction between buildings and other elements of the city (infrastructure, people, ecologies) and aggregate the net impacts on resource use, costs and emissions. Impacts can be expressed using standard indicators of performance. The model must account for the dynamic relationships

between sectors, between resources, and between supply and demand systems, thus allowing developers to accurately estimate and apportion the full costs and benefits associated with Green infrastructure options.

Risk Management

Civil engineering is a discipline that is by nature risk averse. However a number of strategies may be used to manage change and facilitate the acceptance of unfamiliar green infrastructure technologies The first strategy is to reduce the perceived risk by means of three tools:

Pilot tests: Significant changes are best introduced in stages, so that results can be carefully evaluated before widespread adoption. Pilot projects are often the most effective learning tools, and are particularly well suited to green infrastructure. They can happen at a small scale quickly and can take advantage of the redundancy provided by larger existing systems

Contingency plans: The plans must clearly outline the approach to resolving failures, and may actually layer green infrastructure on top of traditional infrastructure for this purpose.

Precedents: Past experience with the same technology can be well documented, and verifies that what is planned has been proven to work well in another location.

A second strategy is to find better ways of sharing risks. Sometimes the risk is disproportionately borne by the developers and professional designers, or by the city engineers and planners that approve and permit the new projects. These people may be risking their careers and reputation because they appear not to be using conventional "professional standards of good practice". Since innovation and experimentation is necessary and ultimately beneficial to the entire community, their risk needs to be underwritten by the community. A revolving performance bond is one example of how this risk can be shared. Essentially a fund is created by all the stakeholders to "guarantee" performance of projects that appear to reflect the best application of green infrastructure principles.

Environmental Management Framework

A comprehensive Environmental Management Framework is another vital tool for steering an effective public process and brokering green infrastructure solutions. Frameworks create a mental map for setting and justifying specific environmental recommendations. They become the underlying structure through which urban developers can transcend motherhood statements and provide tangible, measurable targets for designing, assessing and marketing the performance of a neighbourhood or project. Frameworks have recently achieved considerable success in helping diverse groups reach consensus and create bold visions.

A typical framework can be represented as a pyramid that has, at its top, a definition of sustainable urban development, the fundamental principles of eco-city planning, and the creation of a unique "vision' for the community. From this pinnacle, the Framework divides into a spreading tree of elements, at increasing levels of specificity:

Principles are broad motherhood type statements that are intended to set the direction for all activities and to define the priorities. Stewardship of the natural environment is an example of a principle

Goals elaborate upon the fundamental principles and define the ultimate condition desired. Each principle can have a number of goals associated with it. They indicate the direction of change that is desired. Maintain and enhance the ecological function of the site is an example of a goal.

Key strategies identify basic approaches that can be implemented in order to achieve the goals. Goals can be linked to a number of different key strategies. Generally strategies should be selected that are known to address more than one goal. This is a comprehensive approach which can achieve synergies. Preserve natural drainage patterns on all sites is an example of a key strategy.

Specific Actions provide a range of activities that can be implemented in order to fulfil the key strategies. By virtue of the clear link of key strategies with goals and principles, it is also clear how the specific actions address the higher layers of the framework. Reduce the impermeability of sites is an example of a specific action.

Guidelines and Specifications provide much more detailed information on how to implement specific actions. For example, Guidelines on Reducing Site Impermeability can be prepared.

Monitoring Systems close the loop of the process through tracking and measuring changes in performance on an on-going basis. This information can be used to demonstrate whether a direction is appropriate or whether further changes are required. Monitoring and communication of results are key links to improved environmental performance.

Indicators of Performance
Frameworks work best when combined with performance indicators and targets. Performance indicators quantify the impact of specific actions, and therefore help to determine if the specific actions are being successful in their intent. Targets are a key policy tool for defining ideal levels of performance, and for defining thresholds or "triggers" to govern implementation of policy. Two kinds of indicators are useful:

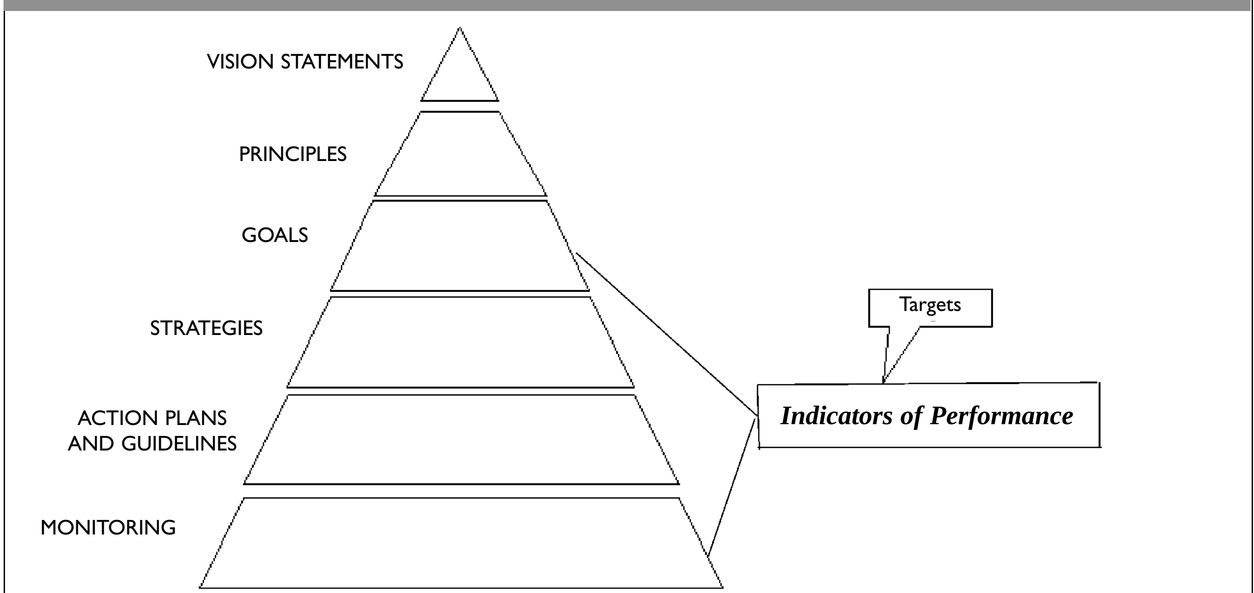
- *Design indicators* are performance values that can be measured or estimated at the design stage, and that can be used to set targets for challenging designers and coordinating and apportioning their effort. Percentage of site area covered in effectively impermeable surfaces is an example of a design indicator. An example of a desirable target would be 10% effective impermeable area.

- *Monitoring indicators* are performance values that can be used to measure how well a particular project is actually performing. They can assist in learning and in setting procedures for managing systems and allocating costs. Percentage change in quality and quantity of water running off the site is an example of a Monitoring indicator. An example of a desirable target might be no net change.

Green Building and Development Guidelines

Barriers to implementation of green infrastructure by developers, and by the design community, include lack of knowledge, lack of time, fear, and perceived cost. These barriers must be overcome by integrating new standards of practice within the standard building design process. Integration can be achieved through a custom set of green building and development guidelines.

Environmental Management Framework



Many residential developers already employ design guidelines for their residential buildings. The best approach is to expand such guidelines to address issues related to environmental performance, healthy housing and green infrastructure. In this way the project can create systems that work effectively at all scales, and that achieve high levels of performance. Some of the content of this Healthy High-Rise Guide can be used as a basis for creating such site-specific guidelines.

Guidelines can cover a broad range of topics and can address both the development planning process, and the building design process. A recent publication[1] for the City of Santa Monica contained 94 separate guidelines for green buildings, and included everything from the site and form of buildings, to energy control systems. Each guideline contained schematics, references, technical guidance and a rating system.
The emphasis must be on providing designers with practical knowledge of solutions, at exactly the time and place when such knowledge is helpful. Information is most needed to answer:

- Who are the suppliers of integrated, tested construction solutions?
- What are the engineering standards?
- What are the most economical methods? and
- What are the maintenance requirements?

Most building designers who make recommendations for servicing systems have only a few hours of design time to consider alternatives. If solutions require lots more time to research than standard technology, there is a built-in disincentive to change. Solutions, therefore, rely on a combination of time-efficient design and implementation solutions - including standard details and specifications and locally available manufactured solutions; and

Fee subsidies, to underwrite the additional design costs, such as the existing Federal CBIP[2] program that subsidises designs for commercial buildings that achieve a minimum energy performance rating.

Experience with guideline implementation suggests that they work best when they are objective-based, and linked to a framework of goals and targets. Guidelines also work better if they include performance-based evaluation procedures wherever possible, since this allows designers to adopt innovative approaches as long as they still achieve the same intent. Finally, guidelines can benefit from existing technical programs and rating systems developed by other authorities. By referencing such 'third party' standards, it becomes possible to simplify the guidelines, and adds support to larger initiatives that may provide on-going technical support. For example, a number of cities have implemented higher energy standards for buildings by simply specifying that developers achieve a level of performance 30% or 50% better than the national energy codes for buildings.

Re-thinking issues of scale and location

Should we be focussed on creating autonomous buildings, self-relient clusters and neighbourhoods or regional networks and grids? In the absence of sophisticated modelling and forecasting tools it is especially difficult for designers and developers to identify the best location and scale for providing green infrastructure. When viewed in isolation, the optimum scales for power supply, heat supply, solid waste treatment and sewage treatment may be different from each other. And as we move towards an integrated circulation system of energy, material and water, we must find the optimum scale of the integrated system. Adding to the complexity is the likelihood that each scale offers difficult trade-offs between economics, environmental impacts, thermodynamic efficiency and community acceptability. For these reasons the design process may fail unless designers recognise that issues are frequently too complicated to be resolved by any single project design team.

One method for coping with the complexity is to use 'rules of thumb' to simplify the decisions, until better tools are available. A rule of thumb for transportation planners, for example, might be: average residents will walk instead of drive, if the distance to shops, transit, and services is no greater than 400 metres. This rule makes it easier to design pedestrian-friendly infrastructure, without sophisticated modelling.

Two broad rules of thumb that can be applied to all green infrastructure projects include:

Adaptable communities need diverse technologies. Thus what seems ‘best practice’ or ‘best value’ at the local scale may not be best if applied everywhere else.

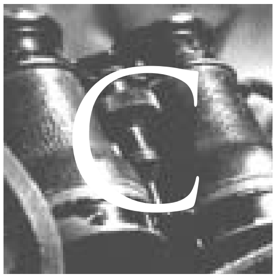
Green infrastructure is evolutionary. In the short term the systems may not be sustainable. However they must create a situation or opportunity that will facilitate changes to longer-term sustainability.

More specific rules are emerging as Canadians explore new approaches to integrating infrastructure with residential building projects.

[1] Sheltair Group, City of Santa Monica Green Buildings Design and Construction Guidelines, 1999.
[2] Commercial Building Incentive Program, National Resources Canada.

Sources of Information

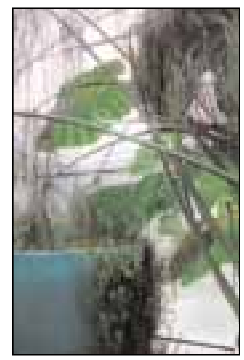
- *The Potential for District Energy in Metro Toronto*, Metro Toronto Works Dept., CANMET NRCan, Ontario Hydro, 1995.
- *Sustainable Investment and Resource Use, Equity, Environmental Integrity and Economic Efficiency, Young*, M.D., Man and the Biosphere Series, New York : Parthenon Pub. Group, 1992.
- Management Systems: Getting Lean, Getting Green in the USA, in *Environmental Management Systems and Cleaner Production*, R. Hillary, John Riley and Sons, 1997.
- *Enivironmentally Sustainable Development Guidelines for Southeast False Creek, A Policy Development Toolkit*, The Sheltair Group, 1998.
- *Guide to Watershed Planning and Management*, Economic Engineering Services Inc., for the Association of Washington Cities, et al, 1999.



CASE STUDY

Canada's First Solar Aquatics Facility Tourist Attraction

BEAR RIVER WASTEWATER TREATMENT PLANT



Solar aquatics is ideal for distributed wastewater treatment in urban environments. Environmental Design and Management (EDM) Limited is a Canadian design company specializing in the development of alternative environmental solutions. EDM designed and built the first two solar aquatics facilities in Canada. The Bear River, Nova Scotia facility was the first municipal system in the world, and has won national and international awards. The system treats liquid waste and has been in operation for over 5 years. The system treats to a very high level of water quality with virtually no odor. The system has few mechanical systems and no chemical inputs.

THE INNOVATIONS

The system uses natural processes to treat sewage and greywater. It consists of a series of selectively designed aquatic ecologies in which wastewater is purified through a progression of complex reactions that absorb the pollutants. Through the use of various levels of phyla (bacteria, algae, snails, plants and fish) to contained marshes, acting as living biofilters, the various pollutants are assimilated. Solar aquatics is more natural than traditional wastewater systems, and in fact filters the water better without harmful chemicals. Currently, 45 homes are connected to the system, 85 are expected.

The Bear River system, with a design flow of 18,000 gallons per day (68,000 litres per day), has been successful from environmental, economic, and social perspectives. Its odour free process allowed was built in the core of the community. Additionally, the community has benefited from increased tourism. It is also estimated that the facility has replaced potential greenhouse gas emissions by 5,685 kg per year, compared to what would normally be exhibited by a sewage treatment plant serving an equal number of homes[1].

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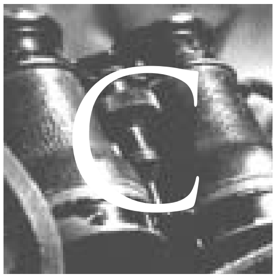
The plant cost under $400,000 to design and build. It was developed under the National Infrastructure Program, with the capital cost being shared between federal, provincial and municipal governments. The net cost to the Municipality was under $135,000, or approximately $4500 per connected household. The cost-per-household is expected to decline by two-thirds with future expansions. The operating costs of the plant are estimated at $45,000-60,000. However, in the future, operating costs are expected to decrease to about $25,000 per year.

[1] http://www.climatechangesolutions.com/english/municipal/stories/default.htm
photographs courtesy of Kimron Rink.

Project Info

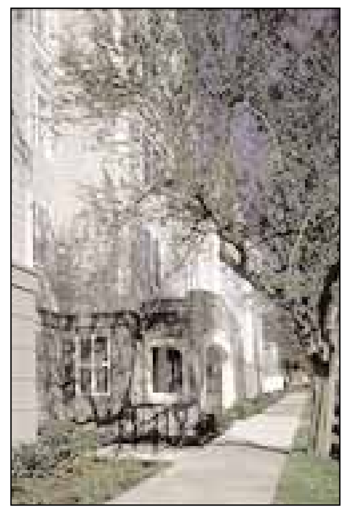
Location:	Bear River, Canada
Designer:	Environmental Design and Management
Number of Dwellings:	45-50 Houses approx. 800 residents
Facility Floor Area:	222 m^2 (2400 ft^2)
Completion Date:	1995
Cost:	$600,000
Further Information:	County of Annapolis P.O. Box 100, Annapolis Royal, Nova Scotia, Canada B0S 1A0 Phone:(902) 532-2331 FAX: (902) 532-2096 Web: http://www.annapoliscounty.ns.ca/solaraqu.htm



CASE STUDY

Portland Inner-city Lot Converted to a Transit-Oriented, Pedestrian Friendly Housing Project

BUCKMAN HEIGHTS DEVELOPMENT



The 3.7-acre infill mixed-use development includes three housing projects and two commercial/retail areas that collectively provide a range of affordable rental housing prices and sizes and the potential for convenient residential services. The development process was highly collaborative, with the general contractor, major subcontractors, engineers and designers all involved in the design process from the beginning. The development illustrated the importance of establishing a dialogue with the various city agencies involved in the implementation of projects.

Environmentally sound business practices were a major goal of the project. The development specified materials with high recycled content for the insulation, sheet rock, carpet pads and finishing materials; participated in construction period recycling, applied low-VOC, non-toxic adhesives and paints for improved indoor air quality, installed Energy Star window (21% more efficient than code), and used continuous ventilation systems. The landscaping is maintained without pesticides, and biodegradable cleaning products are used in the building. Construction costs for the 5-storey 144-unit apartment building (Buckman Heights Apartments) was CAD$97/square foot.

THE INNOVATIONS

The developer chose the property to use existing public transportation and its convenient, underused location. The project is within walking distance of major shopping and community centres, employment districts and recreational facilities. Situated within Portland's central city, the project is located nine blocks from light rail, within five blocks of four high-frequency bus lines, and it is surrounded by a growing network of bike lanes and routes. Locking bike racks, lockers to store bike equipment, tire pumps, and a workstand for resident use are all provided on site. CarSharing Portland, Inc. located several vehicles at the complex. With help from the City of Portland, head-in parking was added to narrow the street, slow traffic and create a pedestrian buffer.

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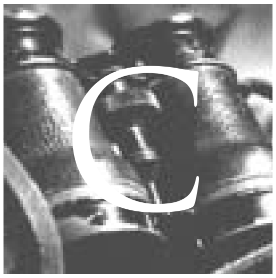
Water use and stormwater management are addressed with low-flow plumbing fixtures and Best Management Practices (BMPs) for stormwater retention. Approximately 95% of stormwater is retained on-site (half of the site possesses 100% on-site retention, the other half experiences 80-90% on-site retention). Stormwater BMPs include narrow driveways, several bioswales, a 185 m^2 extensive green roof, permeable surfaces and a back-up dry well.

Project Info

Location:	Portland, USA
Architect:	William Wilson Architects
Site Area:	3.7 Acres
Number of Dwellings:	Buckman Heights Apartments: 144 Buckman Terrace: 122 Buckman Townhouses: 8
Commercial/ Retail Floor Areas:	185 m^2, 3810 m^2
Completion Date:	1998
Further Information:	Ed Mcnamara Prendergast & Associates 333 SW Fifth Avenue Portland, Oregon USA 97204 Phone: 503-223-8724



CASE STUDY

Halifax Leads Canada in Waste Diversion and Composting

HALIFAX REGIONAL MUNICIPALITY

Organised opposition to a failed landfill and a proposed incinerator resulted in one of the most innovative solid waste management systems in North America. The Halifax Regional Municipality (HRM) has a population base of 350,000, with annual waste generation of 260,000 metric tonnes. In the early 1990s, after years of usage, the wetland area landfill servicing the region, was discovered to have had caused severe environmental damage that affected nearby residents. Ultimately, the HRM compensated the community, approximately $5 million, and bought adjacent homes. The situation prompted a review process to determine a new waste management strategy and resulted in the HRM advanced municipal solid waste management system. This system has significantly reduced the amount of waste that goes to landfill. About 1.4 tonnes less waste per resident, compared to 1995, reached the municipality's landfill site. This represents a 61.5% reduction from 1989 per person volumes. There was also a decrease of approximately 0.5 megatonnes of carbon dioxide equivalent GHG emissions.

The new system did not require a property tax increase. Capital costs of $70.1 million, were financed through a mixture of public and private capital, along with design/build/operate contracts with the private sector. While operating costs for the new systems have been more expensive than the old system, $32.5 million per year compared to $23.4 million, both public and governmental bodies are satisfied with the new system, and consider the additional costs incurred justifiable. Also, a significant portion of the total operating costs (approximately 33%) are recovered through tipping fees[1], and 125 jobs were created through public / private partnerships.

INNOVATIONS

The HRM solid waste management system includes the following:

- Residents are asked to separate their waste into recyclables, compostables and hazardous materials, and other residual refuse. The municipality provides blue bags and aerated carts, and either weekly or biweekly pick-up services.

- Eight collection zones were created (from a previous 25) with six haulers. (The biweekly collection schedule makes it feasible to still use one truck for trash and organics.) The HRM set up a mass balance flow between the eight zones. Organics are collected from four zones one week, and the other four the next. Trash is collected from each of the four on the alternating weeks.

- One site that includes a mixed waste processing facility designed to handle 119,000 metric tons/year of MSW; a 13 channel agitated bed composting system to process the mixed waste after recyclables are removed; and a landfill for stabilized waste.

- Two separate composting facilities with total processing capacity of 61,000 metric tons/year. Both of theses facilities are privately owned and operated, each with put or pay guarantees

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($68.60/metric ton to one compost facility and $65.50 to the other) by HRM of 20,000 metric tons/year.

- Expansion of an existing materials recovery facility.

The recyclable materials are processed at the materials recovery facility (MRF), while the compostables are processed at the two composting facilities. Residual refuse is handled at the mixed waste processing facility. Before residual waste is landfilled it is passed along conveyor lines, where any remaining recyclable materials are removed by hand, and the remaining material is then ground into small pieces and transferred to an 18-day composting plant, to ensure that any residual putrescible material is rendered inert. Anything remaining after this process is then transferred to the new, virtually methane-free, residual disposal facility that has no odour problem, does not attract vermin or birds, and does not require an on-site leachate collection system.

During the new system's first nine months of operation, from January to September 1999, the amount of waste that required landfilling was 40% less than the previous year. However, the amount of commercial, industrial and institutional waste (ICI) (including waste from apartment buildings) fell only by eight per cent, resulting in some waste being temporarily exported to the neighbouring Queens region for landfilling. While the ICI sector is responsible for its own waste collection, the HRM does encourage the separation of compostables at source in two ways: (1) by setting differential tipping fees ($68/tonne for compostables and $110/tonne for residual refuse); and (2) by reserving the right to refuse unsorted loads that are delivered to the front-end processing/ waste stabilisation facility. Today, the total solid waste stream is roughly 55 percent residential and 45 percent commercial.

Not all of the 260,000 metric tons generated annually will go through the new HRM system. Construction and demolition debris, which accounts for 40,000 to 60,000 metric tons/year, and recyclables from the commercial sector go to private operators. This leaves roughly 190,000 for the HRM facilities and contractors to process. The design capacity is for 460 tons/day to come into the front end of the mixed waste facility. Even if the facility over capacity on the front-end, it can not dispose of anything directly into the landfill.

[1] Assumes $32.5 million operating costs and tipping revenues of $10.6 million (projected 2000/01).

Project Info

Location:	Halifax Regional Municipality (HRM), Nova Scotia
Implementation Date:	1999
Further Information:	Brian T. Smith Halifax Regional Municipality Solid Waste Resources 2776 Dutch Village Road P.O. Box 1749 Halifax, NS B3J 3A5 Phone: 902-490-6600