Ventilation, Indoor Moisture Loads, Humidity Control, and Energy Efficiency

Books and Research Reports

Perkins+Will Canada

*Greenhouse Gas Implications of HVAC Upgrades in Multi-Unit Residential Buildings*

Burnaby, BC, Canada: Homeowner Protection Office

2015

This Research Report explores best practices and approaches for reducing greenhouse gas (GHG) emissions through heating, ventilation, and air-conditioning (HVAC) upgrades in multi-unit residential buildings (MURBs) in British Columbia. The aim of this Research Report is to support industry in making informed HVAC upgrade decisions that can lead to greenhouse gas savings. As heating energy accounts for approximately 65% of the total energy consumption, focusing on improving energy efficiency for heating the building, fresh air and domestic hot water provides the most opportunity for reductions. A checklist of different upgrade opportunities to consider is presented. Commissioned by BC Housing and prepared by Perkins+Will, this report is based on:

- a review of industry best practices;
- research previously completed by Perkins+Will for BC Housing on greenhouse gas reduction strategies for MURBs through HVAC upgrades; and,

Available at: HPO

Canada Mortgage and Housing Corporation

*Approaching Net-Zero Energy in Existing Housing*

Ottawa: Canada Mortgage and Housing Corporation

2008

“CMHC defines .net-zero energy housing. as a home that produces as much energy as it consumes annually. This research looks at existing homes of different types and ages in various climatic regions across Canada in an effort to determine the technical feasibility of retrofitting to achieve net-zero energy consumption. Building envelope upgrades are critical, with photovoltaic (PV) systems, high-performance windows, and high-efficiency heating and ventilation equipment also contributing to savings. Some existing houses could be transformed to net zero energy. The methods and costs are outlined in the report.”

Available at: CMHC

RDH Building Engineering Ltd., Innes Hood Consulting, Ken Farrish Marketing and Constructive Home Solutions

*Best Practices fro Air Sealing and Insulation Retrofits*

Burnaby, BC, Canada: Homeowner Protection Office

2015

This guide consolidates best practices for air sealing and insulation weatherization work in an easy to follow format. A valuable reference tool for builders and other industry professionals, it
addresses British Columbia’s unique climate, construction practices, and building code requirements. Available only online, the guide includes: Procedures for common air sealing and insulation installation measures for attics/roofs, above-grade walls, basements, crawlspaces and floors. Contractor checklist for home air sealing and insulation procedures. Homeowner tips to assist with operation and maintenance. Health and safety considerations. Extensive list of additional resources and references.

Available at: HPO

Canada Mortgage and Housing Corporation
*Field Testing to Characterize Suite Ventilation in Recently Constructed Mid- and High-rise Residential Buildings.*
Ottawa: Canada Mortgage and Housing Corporation
1999

“Mechanical ventilation systems in multi-unit residential buildings typically consist of central corridor air supply systems and central, or individual, suite exhaust systems. This approach has not significantly changed over the past 30 years despite evidence that such systems are neither effective nor efficient. This research project conducted a study of 10 mid- and high-rise residential buildings to assess the performance of the mechanical ventilation systems and to identify influencing design, installation, operational, and environmental factors. The study provides many useful insights as to why conventional ventilation strategies are unable to meet the ventilation requirements of multi-unit residential buildings.”

Available at: CMHC

Canada Mortgage and Housing Corporation
*Investigating Moisture in Seasonal Housing*
Ottawa: Canada Mortgage and Housing Corporation
2001

“This research looked at the sources of moisture problems in dwellings that remain unoccupied for long periods of time. Changes were recommended to counter the identified moisture problems. Foundation problems were identified as the primary source of excessive humidity; there was also some evidence of temperature and humidity conditions leading to spring/winter condensation.”

Available at: CMHC

Canada Mortgage and Housing Corporation
*Achieving Healthy Indoor Environments: A Review of Canadian Options*
Ottawa: Canada Mortgage and Housing Corporation
2002

“There is convincing evidence that poor indoor air quality (IAQ) is a top environmental risk to human health. This report explores the question of whether government regulations or voluntary initiatives are more appropriate for solving indoor air quality problems.”

Available at: CMHC

Canada Mortgage and Housing Corporation
*Compliance of Ventilation Systems Installed to Meet Proposed Changes to the 1995 NBCC*
Ottawa: Canada Mortgage and Housing Corporation
2002
“The research program involved inspecting and testing houses with ventilation systems designed and
installed to meet the proposed residential ventilation requirements. The study was to evaluate the
effectiveness of the proposed code changes at dealing with shortcomings in the 1995 National
Building Code of Canada (NBCC).”
Available at: CMHC

Canada Mortgage and Housing Corporation
Ventilation Systems for Multi-Unit Residential Buildings: Performance Requirements and Alternative
Approaches
Ottawa: Canada Mortgage and Housing Corporation
2003
“Multi-unit residential buildings (MURBs) represent a significant and growing proportion of
housing in Canada. While there have been many advances in building technologies, ventilation
strategies have not changed significantly over the past three decades. Existing ventilation
systems are unsatisfactory in most aspects. This project established reasonable ventilation rates
and related performance parameters. Four possible alternative systems were analyzed for benefits
and drawbacks. Most are still in their early stages of development and will need more research,
but the housing industry can help support these alternative approaches.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Improved Make-Up Air Supply Techniques
Ottawa: Canada Mortgage and Housing Corporation
2004
“As houses become more airtight, natural leakage is not adequate to replace exhausted air. This
research examined systems that bring fresh air into the house, and generally found them
inadequate. Passive and fan-based techniques were studied, as well as a prototype system built
specially for the purpose. Since the publishing of this work, there has been an increasing trend
to the installation of backdraft-resistant appliances, due to changes in codes, standards, and
industry practice in Canada.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Analysis of Ventilation System Performance in New Ontario Houses
Ottawa: Canada Mortgage and Housing Corporation
2004
“As newly built homes become more airtight, proper ventilation becomes more important, due to the
potential for combustion spillage. The current Ontario building code allows for the independent
operation of the exhaust-only ventilation system (EOV) and the furnace circulation fan. A
recent survey of new homes shows that three-quarters have the EOV system, and of those, only some
13% of owners use the system properly. Future Ontario codes should require the interlock of the
ventilation fan and the circulating fan.”
Ventilation strategies for apartments have not changed significantly over the past 30 years, despite significant evolutions in design and construction. CMHC evaluated seven prototypes of an integrated ventilation-space conditioning (VSC) system that combines the function and familiarity of vertical fan-coil units with an innovative heat recovery ventilation (HRV) system. Research found that there are now viable alternatives to conventional ventilation systems that are both possible and practical. However, there are still many unexplored issues surrounding the design, installation and performance of in-suite ventilation systems in multi-unit buildings that must be addressed before the application of in-suite systems becomes commonplace.”

Canadian homes built in the last several decades are too tight to provide the right amount of ventilation by random infiltration. This research, analysing homes in Ottawa, Vancouver and Saskatoon, looks at when supplemental mechanical ventilation might be needed. Based on the assumption that houses need ventilation rates of at least 0.3 air changes per hour, research found tight houses in cold climates, such as Saskatoon, required additional mechanical ventilation practically the whole year to reach that target. In Vancouver, where houses are less airtight, natural ventilation can be adequate for longer periods. The research confirms the need for mechanical ventilation generally, and can help builders or homeowners by showing when to activate ventilation systems.”

The objectives of this study were to determine a practical and cost-effective method of assessing the effectiveness of dehumidifiers in controlling moisture in houses, and to assess the usefulness of dehumidifiers in controlling general moisture conditions in houses in different regions of Canada. Results showed that in most regions of Canada, dehumidification is beneficial during the non-heating season, while year-round operation can be beneficial for houses located in milder coastal climates.”

Garden, G.K.
Ventilation, Indoor Moisture Loads, Humidity Control, and Energy Efficiency

**Canadian Building Digests, CBD-72**
Ottawa: National Research Council of Canada, Division of Building Research
1965

“Air leakage is the uncontrolled movement of air through walls and roofs, both into a building (infiltration) and out of it (exfiltration), and the interchange of air from the building with that in spaces in the building envelope. Pressure differences that cause infiltration and exfiltration are produced by wind, chimney effect, and the operation of mechanical ventilation systems.”

Available at: BCIT, VPL, UBC, NRC-IRC

Hansen, A.T.

**Canadian Building Digests, CBD-231**
Ottawa: National Research Council of Canada, Division of Building Research
1984

“Winter moisture condensation is probably the most common moisture-related problem that affects houses. In its mildest form, it appears only as harmless surface condensation on windows. In severe cases it causes decay that might affect the structure itself. In between these extremes, it can manifest itself as mildew growth on the interior finish, or as ceiling stains, ceiling leaks or paint peeling.”

Available at: BCIT, VPL, UBC, NRC-IRC

Haysom, J.C. and J.T. Reardon

**Construction Technology Updates, No. 14**
Ottawa: National Research Council of Canada, Institute for Research in Construction
1998

“A house needs a third of its air exchanged every hour. Owners of houses built before 1960 relied on air leakage through the building envelope for indoor/outdoor air exchanges. And they could, because houses then were leaky enough and wind or temperature difference saw to the necessary air movement. In the 1960s, houses became more airtight, and some were heated electrically (they did not even need a chimney). In the 1970s with its oil crisis, houses became even more airtight. With little air leakage through the building envelope, a mechanical ventilation system is required for moisture and pollutant removal. So, the question now is: how does one ventilate optimally?”

Available at: NRC-IRC

Haysom, J.C. and J.T. Reardon

**Construction Technology Updates, No. 15**
Ottawa: National Research Council of Canada, Institute for Research in Construction
1998

“In many ways the 1995 National Building Code (NBC) parallels and complements the CSA standard CAN/CSA-F326 in defining current approaches to mechanical ventilation in houses. Whereas F326 does not stipulate a maximum sound output, the NBC, for example, does: 53 decibels. The NBC gives details about the interrelationship of air intake and air output and the role various types of fans must play in houses that are either with or without a forced-air heating system. Houses without a forced-air heating system can also present problems in the even distribution of outdoor
Humidity is one of the most important of the topics that are of special concern in Canadian building design and operation. Low outdoor temperatures in winter give rise to condensation on and in walls and windows and tend to produce low relative humidities indoors. When even moderate humidities must be carried within buildings serious difficulties can be expected unless the designer appreciates fully what humidity is and how it relates to building performance. It is important to realize that what is normally referred to as "humidity" is actually relative humidity. It is a measure of the amount of water vapour present in the air expressed as a percentage of the maximum amount that the air can hold at that particular temperature. When the temperature is changed, the relative humidity changes, since the capacity of the air for holding moisture increases with increasing temperature. These relationships are most conveniently represented graphically in psychometric charts.

Hutcheon, N.B. (editor)
*Canadian Building Digests, CBD-1*
Ottawa: National Research Council of Canada, Division of Building Research 1960

Available at: VPL, BCIT, UBC, NRC-IRC

Modera/Persily (editors)
*STP 1255: Airflow Performance of Building Envelopes, Components and Systems*

Available at: www.astm.org

Sherman, M.H. (editor)
*STP 1067 Air Change Rate and Airtightness in Buildings*

Available at: www.astm.org
peer-reviewed papers appear in sections on tracer gas techniques, air exchange rate measurement, residential airtightness, multizone leakage, and comparison of techniques. For blower door contractors, researchers, specification writers, government agencies.”
Available at: CMHC, www.astm.org

Canada Mortgage and Housing Corporation
Thermostat Settings in Houses with In-floor Heating
Ottawa: Canada Mortgage and Housing Corporation
2001
“An investigation into the relationship of in-floor radiant heating and thermostat settings.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Effects of Thermostat Setting on Energy Consumption
Ottawa: Canada Mortgage and Housing Corporation
2001
“This study measures the energy savings from thermostat setback (in winter) and set forward (in summer) in R-2000 houses at the Canadian Centre for Housing Technology. In order to reduce energy use, many households adjust their thermostat settings when occupants are not at home, or are asleep. The research demonstrates the benefits of this relatively simple energy conservation measure. Results vary in less efficient houses, and set-backs could lead to condensation and mold in some houses.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Assessment of the Energy Performance of Two Gas Combo-Heating Systems
Ottawa: Canada Mortgage and Housing Corporation
2001
“Combo heating systems use a water heater to produce heat for both space heating and domestic hot water heating. This research project compared the performance of two combo systems in the CCHT's test house facility. The tests confirmed that combo systems can meet the combined load requirements of water and space heating for a dwelling.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Case Studies of Major Home Energy Retrofits
Ottawa: Canada Mortgage and Housing Corporation
2003
“Five homeowners in Saskatchewan agreed to implement a variety of retrofit energy saving measures, at their expense, as recommended by the HOT2000 computer model. These ranged from simple items such as compact fluorescent lamps to the retrofit of high efficiency furnaces. Total energy consumption reductions ranged from 24% to the target of 40%. Those not meeting the target could be attributed to homeowners not following all the HOT2000 recommendations and lifestyle changes. Payback periods ranged from 8.4 to 16.5 years. All homeowners were satisfied with the savings they
Canada Mortgage and Housing Corporation

*Energy Needs and Availability in Housing*
Ottawa: Canada Mortgage and Housing Corporation
2004

“This study estimates the amount and type of energy required to provide a variety of household services, compares these needs with the energy consumed, and determines the sources of energy available in the house and on the lot. The research shows that improved design is required to match household devices to energy needs. Using more waste heat and energy sources with high fuel cycle efficiencies would greatly improve energy ratios and efficiencies. Use of on-site heat recovery and ambient energy should be increased. Solar and wind energy, and geothermal heat could, with the appropriate conversion devices, be utilized to meet significant portions of an efficient dwelling’s energy needs.”

Available at: CMHC

Canada Mortgage and Housing Corporation

*Strategies for Reducing Building Energy Use Via Innovative Building Envelope Technologies*
Ottawa: Canada Mortgage and Housing Corporation
2004

“Over the past decade, many new technologies have been developed and introduced to the building industry that can recover, generate or save energy at the outer envelope of buildings. This research examined which of these technologies would be most acceptable to the owners of aging multi-unit residential buildings requiring renovations. While several technologies are appealing, such as enclosing balconies, the current economics and risk associated with many of the available technologies can undermine their attractiveness to property owners.”

Available at: CMHC

Canada Mortgage and Housing Corporation

*Analysis of Renewable Energy Potential in the Residential Sector through High-Resolution Building-Energy Simulation*
Ottawa: Canada Mortgage and Housing Corporation
2008

“This study provides technical assessment of the potential of renewable energy systems, specifically roof-mounted solar photovoltaic (PV), micro-wind turbine, renewable energy-based heating, ventilating and air-conditioning (HVAC), and domestic hot water (DHW), in low-rise housing. The project demonstrates that the generation of renewable energy in the residential sector can lower consumer costs and meet part of the overall energy demand. But it concludes that without significant reduction of the overall energy consumption, these technologies alone cannot meet energy needs in the residential sector.”

Available at: CMHC

Canada Mortgage and Housing Corporation
Drain Water Heat Recovery Performance Testing at CCHT
Ottawa: Canada Mortgage and Housing Corporation
2008
“This report provides test results from a simple energy savings device that recovers waste heat
from showers to preheat domestic hot water. Several models of these drainwater heat recovery
devices were tested at the Canadian Centre for Housing Technology (CCHT). A link to an energy
savings calculator is provided to calculate which brand of device is best suited to your
household.”
Available at: CMHC

Canada Mortgage and Housing Corporation
Monitoring Results for the Factor 9 Home
Ottawa: Canada Mortgage and Housing Corporation
2009
“The Factor 9 Home demonstration project is a single-family residence in Regina, Saskatchewan,
featuring high levels of energy and water-use efficiency. This research project monitored the
home's energy and water use for a one-year period in order to assess whether performance
objectives were being met. A number of indoor air quality indicators were also measured. The
monitoring showed that the house met its target of reducing annual energy usage to about 10% of
the average existing home in Saskatchewan.”
Available at: CMHC

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Buildings 0: 285-298
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Bagge, Hans; Johansson, Dennis; Lindstrii, Lotti. 2010. Indoor Hygrothermal Conditions in
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