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2018 Housing R&D Highlights

Envelope systems | Mechanical systems | House as a system

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2018 Housing R&D Highlights

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Envelope systems

- For new construction
- For retrofits
- Cost-effectiveness for the North

Mechanical systems

- Cold-climate air source heat pumps
- Guidelines for the application of innovative technologies

House as a system

- Options for net-zero housing design
- Cost-effectiveness of energy efficiency measures across Canada
- Cost-effectiveness of technology packages for step codes

CanmetENERGY-Ottawa

Federal R&D in

- energy efficiency
- clean energy
- regulations
- codes & standards

Buildings and communities R&D

- energy-efficient housing and buildings
- advanced mechanical systems
- renewables integration
- smart energy networks

Envelope systems

Status: First pilot completed at the Bells Corners Complex

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Prefabricated Exterior Energy Retrofit

Description

In retrofit programs to date, exterior wall insulation improvements have been uncommon, even though walls often account for 25 to 35 percent of the heat loss of a typical existing home. As Canadian jurisdictions introduce carbon pricing and policies targeting net-zero energy housing, significant levels of investment can be anticipated in housing energy retrofits in the coming years.

The Prefabricated Exterior Energy Retrofit (PEER) project seeks to develop technologies and processes for applying prefabricated components to retrofit existing homes and buildings from the exterior. This approach promises to dramatically improve energy efficiency and enhance aesthetics while reducing the cost and complexity of a conventional retrofit.

Guided by an advisory committee to provide technical guidance and market intelligence, the project team will collaborate with industry partners to create technology specifications and build and test prototype prefabricated panels. The research will investigate and refine the workflow for converting 3D scans done on-site into digital files for use by manufacturers to build custom panels for specific retrofit projects. Field tests of prototype prefabricated wall systems will be conducted to evaluate thermal and moisture performance as well as cost-effectiveness. Finally, a technology development and deployment plan will be generated for commercialization of prefabricated wall systems for deep energy retrofits.

Findings

The first pilot of a building on the Bells Corners Complex was completed in October 2017. Two prototype wall panels were installed on a small building and a pitched roof was added. Post retrofit airtightness of 0.89 ACH @ 50 Pa was achieved. Space heating demand is expected to be reduced by 64 percent, enabling net-zero ready performance.

Survey of conventional retrofit and replacement practices for residential wall assemblies

Description

Canada's housing stock consists of more than 11 million low-rise detached, semi- and row-attached dwellings. More than two thirds of these dwellings were built before the existence of the residential energy efficiency standards. These existing homes are ripe for energy efficiency retrofits. Several barriers and information gaps related to exterior wall retrofits exist, such as deciding on what kind of retrofit process to use; dismantling and removing existing cladding; preparing the exterior surfaces; installing insulation and new cladding; and taking into account the different methods of exterior wall retrofit considered by contractors.

The purpose of this project is to benchmark conventional exterior cladding replacement and retrofit methods for proposal costing, retrofit work processes, technical challenges and trade skills, final installation, and other associated issues.

Findings

Findings of this study are intended to highlight opportunities and challenges of exterior envelope retrofits of existing low-rise residential buildings. The study should provide an assessment of current retrofit processes and offer recommendations to improve the retrofit measures, delivery and, above all, options for lowering the cost of retrofits for significantly improving the energy efficiency of a dwelling.

Envelope systems

Status: Final report available

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Envelope systems

Status: Final report available summer 2018

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Field performance and constructability of vacuum-insulated, thin wood-frame wall assemblies

Description

High performance housing standards (R-2000*, net-zero energy, Passive House) in Canada require high levels of insulation compared to code-built homes. Home builders have traditionally employed thick wall assemblies that are often twice as deep as conventional walls to achieve the necessary thermal resistance (typically RSI 5.0–8.8 [R-28–50]). Because walls cannot protrude beyond zoning setbacks, these thick walls negatively affect the livable area. This has a real cost to buyers (as high as $25,000 per home in urban markets) on top of the additional materials and labour necessary. This is a significant barrier to adoption of energy-efficient housing. To help address this, CanmetENERGY is developing and evaluating high-R, thin wall systems.

The main objective is, at the minimum, to double the thermal resistance of a conventional code-built wall in a similar thickness to achieve RSI 7.9 (R-45) or higher.

Findings

Each of the innovative concept walls is comprised of wood framing, composite vacuum-insulated panel (VIP) and extruded polystyrene (XPS) insulating sheathing. The panels consist of 38 mm x 89 mm wood framing with 25 mm VIP sandwiched between 12.5 mm XPS layers. The configuration of the VIPs within the XPS was designed to minimize thermal bridging. The composite panels can be installed horizontally to accommodate framing on 410 mm centres or vertically to accommodate framing on 305 mm or 610 mm centres. Both these assemblies ensured overall insulation value of RSI 8.6 (R-49).

These wall assemblies were first modelled within the THERM heat transfer analysis program to predict and optimize thermal resistances. Prototypes were then constructed, instrumented, installed and evaluated in situ in the CanmetENERGY Building Envelope Test Facility in Ottawa. Temperature and humidity inside the facility were controlled, and the assembly exteriors were exposed to transient outdoor conditions. The temperature across the profile, heat flux, relative humidity in the cavity, and moisture content of the framing and sheathing were monitored over 12 months.

*R-2000 is an official mark of Natural Resources Canada.

Northern panelized MURB systems

Description

The objective of this project was to determine the relative costs of five pre-fabricated insulated wall systems for low-rise (Part 9) northern multi-unit residential buildings (MURB).

Five types of walls were developed by the author and then analyzed – four panelized (types A to D) and one modular (i.e. fully finished, ready-to-move boxes: Type E). Performance for the exterior walls was set at an effective thermal resistance of RSI 7.04 (R-40). All panel types were based on light-wood structural framing.

To simplify the cost analysis, all costs were given for a wall length of 30 m (100 ft.). The "selling price" was determined for 30 m of each panel type (not for the modular option) based on material costs, labour and production rates, and standard profit and overhead margins used by an established panel manufacturer.

The method of packaging for shipment was determined on the basis of a panel's susceptibility to physical and water damage during shipment and storage on site. A cost for packaging 30 m of each type was then calculated based on published rates for these services. Shipping costs to six communities were determined: one in each of Yukon, the Northwest Territories, the Nunavik region of Quebec, the Nunatsiavut region of Newfoundland and Labrador, and, because of its large geographic area, two regions in Nunavut. Weights and volumes for the packaged panels were calculated, and shipping costs to each community were established based on published or quoted rates for either sealift, barge or flatbed truck.

Findings

The difference in price between the most and least expensive panel types was almost 100 percent, with the two least expensive differing by about 20 percent.

Envelope systems

Status: Final report available

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Envelope systems

Status: Final report available March 2018

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Windows R&D opportunities and barriers analysis

Description

Recently, the Equipment Division of Natural Resources Canada's Office of Energy Efficiency organized a workshop on market transformation for residential windows. The main goal of this workshop was to lay out the plan for aspired energy performance targets for windows and to gather industry support to achieve these ambitious goals. The outcome of this workshop helped support the drafting of high-level market transformation strategies for consideration at the Energy and Mines Ministers' Conference. One of the aspects raised in these consultations relates to identifying the status of the window industry in meeting the aspirational goals and capacity of R&D organizations and industry, as well as of industry associations.

The main objective of this project is to provide information about the current state of window technologies (i.e. components and products) and the key contacts for the industry, R&D labs, and regulatory and public sector agencies.

Long-term performance of vacuum insulated panel walls and energy use assessments of a net-zero energy house

Description

Canada's pioneering EQuilibrium™ Homes Initiative, developed and sponsored by Canada Mortgage and Housing Corporation (CMHC), supported the construction of several net-zero energy demonstration homes across Canada, in 2011. One of the most successful projects, Harmony Home in Burnaby, British Columbia, demonstrated the use of vacuum insulated panels (VIP) for above-grade walls, low U-factor windows, high performance mechanical systems, and grid-connected photovoltaics to achieve zero energy levels. The exterior VIP wall assemblies consisted of 15 mm thick VIPs in the centre of the stud cavity covered by a 50 mm foil-faced isocyanurate foam board on the exterior and open cell spray foam on the interior. They provided an estimated effective insulation, averaged over the entire wall, of 38.5 sq. ft.F/Btu (R) or 6.8 m^2K/W (RSI).

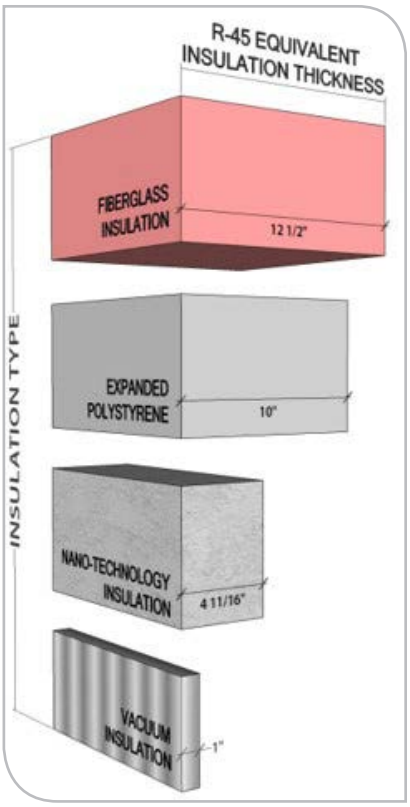
The main objective of the field study was to evaluate the long-term performance of this home after six years of operation. The evaluation looked at heat transmission through the building envelope, moisture performance of VIP wall assemblies and annual energy consumption.

Findings

The thermographic survey of wall assemblies and joints showed that the VIPs are intact and, overall, that the building envelope is in excellent condition. In situ wall assembly moisture measurements, gathered in four wall sections in different orientations within the framing and sheathing, showed no appreciable moisture accumulation.

The energy use data over a period of five years showed the following varying trends: (1) photovoltaic systems were performing as per the design intent but on a year-to-year basis, there was a significant ±20 percent variation in electricity generation; (2) occupant-driven load showed little change; and (3) significant variations were documented in space heating and space cooling requirements. Detailed data analyses showed that the year-to-year variations were mainly due to climate conditions. On the whole, the Harmony Home demonstrated comparatively close to net-zero energy performance (±5 percent) over the years.

This project showed that proper design and construction of wall systems with VIPs do have merits in our climate. With the steady occupant loads, a net-zero home does provide expected energy performance over the years.



Envelope systems

Status: Final report available December 2018

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Mechanical systems

Status: Draft performance rating under review

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New performance rating procedure for variable capacity air source heat pumps

Description

The forthcoming Canadian Standards Association performance rating entitled Energy performance of split-system and single-package air conditioners and heat pumps will provide an alternative approach to testing the performance of air source heat pumps and air conditioners.

In the past, performance test procedures have assessed the performance of equipment at fixed capacity, steady state conditions. This procedure uses a dynamic load-based approach in which the equipment is allowed to respond with its “as shipped” controls to an imposed load. This allows the actual behaviour of the equipment and controls to be measured in the test facility in a manner more representative of conditions that would exist in a home or building. The performance rating also includes the measured performance losses caused by defrost rather than by applying a prescribed performance penalty as is the case in current standards. And lastly, the new procedure allows for testing down to an outdoor temperature of -26°C (-15°F), well beyond that of current ratings procedures that require testing down to a minimum outdoor temperature of -8.3°C (17°F).

By sharing knowledge gained through testing at newly developed test facilities, CanmetENERGY Ottawa and Varennes have made key contributions to the development of this performance rating procedure.

PV ready guidelines

Description

The *Photovoltaic Ready Guidelines* describe design considerations and specify modifications that builders can make to new attached and detached homes in preparation for installing a photovoltaic (PV) system. The design considerations and modifications include the following elements: roof space, PV conduit and wall space next to the electrical panel. Structural loading considerations are discussed in the guidelines.

The guidelines are intended to be simple and inexpensive to implement, while enabling significant savings in installation costs should a homeowner choose to install a complete PV system in the future. The *Photovoltaic Ready Guidelines* specifically target the installation of PV modules and components as tested and/or certified according to relevant Canadian Standards Association test standards and as installed by qualified installers.

The guidelines have been developed in response to a request from CHBA Net Zero and CanSIA for a design guide specific to PV systems. A comprehensive consultation with industry via CHBA, CanSIA members and others has been completed.

House as a system

Status: Final editing for publication to the NRCan website

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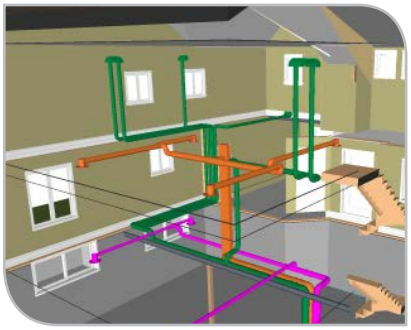

Mechanical systems

Status: Completed; advanced copies available upon request

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Zoning Duct Design Guide

Description

This *Zoning Duct Design Guide* was developed to provide mechanical designers with a generic approach for designing zoned ducting systems that are compatible with most forced-air equipment. It builds on design information communicated in the *Zoning Checklist for Builders*, available in the Natural Resources Canada's *Zoning Decision Guide for Builders*.

The guides are informed by consultation with a broad range of industry professionals and build on 10+ years of research, development and demonstration activities.

Development and field validation of airtightness test procedures for low-rise multi-unit residential buildings

Description

Low-rise multi-unit residential buildings (MURB) is the fastest growing segment of Canadian housing. Urban developments and affordability are some key reasons for the popularity of attached, condominium, and apartment-style residential buildings. Over the years, we have focused more on improving the energy efficiency of single family detached and attached housing and have achieved great success.

However, the MURB segment is falling short of meeting the current energy efficiency targets. One of the main reasons for this is their loose construction with much higher air infiltration rates. Airtightness testing of a MURB is a technically complex procedure. There are few methods for evaluating the airtightness of MURBs. The main aim of this project is compare these methods and make a qualitative assessment of appropriate choices.

The overall objective of this project is to develop an improved, practical, yet accurate technique for measuring the airtightness of partition surfaces in MURBs – specifically, low-rise MURBs.

Findings

Two specific methods were developed and evaluated to determine the partition leakage between two adjacent units, by conducting a standard CGSB 149.10 test on the first unit (i.e. the test unit), while simultaneously measuring the pressure differential created between the test unit and the adjacent unit. These methods were evaluated on three MURBs, and they validated the method. The airtightness test protocol was developed for the airtightness testing of low-rise MURBs.

House as a system

Status: Final report available

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House as a system

Status: Final report available March 2018

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Field assessment of houses to test and validate the HOT2000* version 11 energy performance

Description

HOT2000 is an energy simulation tool for low-rise residential buildings that is used widely across Canada to support program, policy, and regulatory development and implementation. Over the last three decades, HOT2000 has been a de facto choice for energy advisors in the Canadian residential market for energy analysis. HOT2000 has been used in evaluating the energy efficiency of more than 1.1 million homes (i.e. ~10 percent of Canadian low-rise dwellings). HOT2000 is based on a modified bin method for evaluating whole building energy analysis using monthly average weather data. It uses a combination of building physics and curve-fits developed from detailed simulation software. Over the last 30+ years, HOT2000 has been modified, expanded and regularly updated. The most recent version is 11.3. Recently, HOT2000 was evaluated according to ASHRAE Standard 140-2014. The results showed good comparison and compliance, as per the requirements.

The main objective of this project is to assess and evaluate the energy use predictions of HOT2000 for 25 to 40 homes, preferably in different climate zones and at different energy efficiency levels. The validation process will include house energy evaluation, weather normalization and reconciliation with utility bills. Further assessments will include comparisons with EnerGuide Rating System (ERS), different modes with operating conditions and 30-year average weather data.

*HOT2000 is an official mark of Natural Resources Canada.

Role of NRCan's housing programs in the marketplace

Description

Canada's buildings and housing sector is responsible for 12 percent of greenhouse gas (GHG) emissions annually. Increased energy efficiency in this sector will not only reduce GHG emissions but will also help homeowners improve their bottom line through energy cost reductions.

Energy use in new buildings can be reduced through more stringent building codes, including a requirement for buildings to be net-zero energy ready. These buildings are so energy-efficient that, with the addition of renewable power generation (e.g. solar panels), the building becomes a net-zero consumer of energy. Such a building supplies as much energy to the grid as it consumes over the course of a year.

Several provincial, territorial, and national regulatory agencies have already signalled their intention to develop an energy code roadmap (i.e. tiered code or step code). Consequently, Natural Resources Canada's (NRCan) housing programs, ENERGY STAR™ for New Homes and R-2000, need to be assessed for the potential to be integrated for tiered codes.

The objective of this work is to develop a discussion document that includes options and recommended course(s) of action for aligning NRCan's new housing brands with tiered codes and net-zero energy performance.

House as a system

Status: Final report available March 2018

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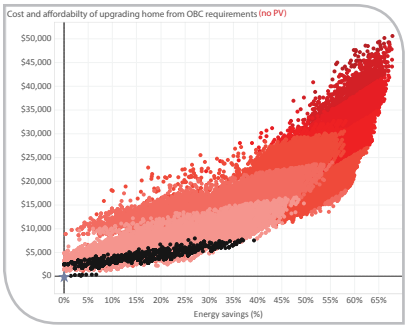

House as a system

Status: Final report available

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Feasibility and cost-benefit analysis of step codes

Researchers at CanmetENERGY-Ottawa applied the housing technology assessment platform (HTAP) to examine the costs and benefits of the *BC Energy Step Code*. The researchers provided the HTAP toolkit and cloud computing resources to BC Housing and local energy experts. They worked with those groups to analyze over a million design scenarios for single family and multi-family housing throughout British Columbia.

The results from this study highlight the energy savings and ownership cost impacts of constructing homes according to the step codes. Researchers at CanmetENERGY-Ottawa will also use findings from this work to inform future renewal of the *National Building Code of Canada*.

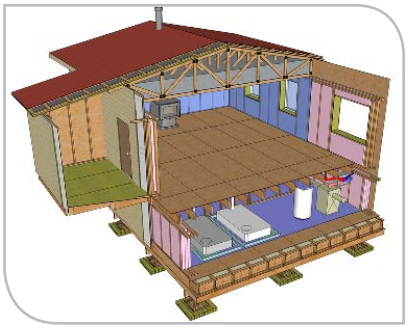
Feasibility study for Passive House and near net-zero standards for the North

Description

Worldwide, buildings account for about one third of energy-related greenhouse gas emissions. Because future building codes will base performance levels on existing programs such as Passive House, there is a need to understand how these energy targets can be achieved in the world's harshest climates.

The *BC Energy Step Code* and the Passive House standard are very effective methods for achieving energy efficiency in the built environment. However, the question of whether these standards are feasible in extreme climates in the far north remains. There is a need to understand the barriers to implementation in northern locations where there are significant opportunities to minimize heating demand. In remote arctic communities, it means less reliance on locally generated power and the ability to construct new dwellings without overloading local energy capacity.

The goal of this project is to assess the feasibility of building to the international Passive House standard and near-net-zero for a range of building types in Canada's North, including the Northwest Territories. It will address climate- and location-related limitations of the international Passive House standard and near net-zero, while identifying strategies for achieving these performance levels all the way to the far north.



House as a system

Status: Final report will be available in July 2018

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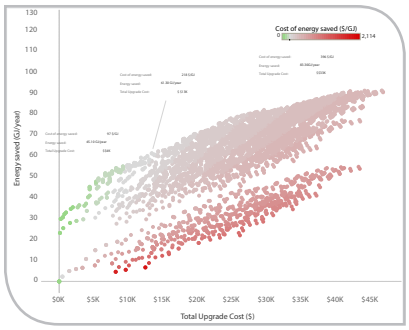

House as a system

Status: Complete

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Aspirational targets for future residential equipment

Description

In 2016–2017, CanmetENERGY-Ottawa researchers worked with Natural Resources Canada's (NRCan) Office of Energy Efficiency to examine the outlook for next-generation space heating, water heating and window technology under different energy price forecasts. This study explored the following next-generation scenarios.

Space heating	• Replacing electric resistance and oil heating with next-generation cold-climate heat pumps and mini-splits • Replacing gas furnaces with gas-fired heat pumps
Water heating	• Replacing electric resistance and oil water heaters with next-generation heat pump water heaters • Replacing gas water heaters with gas-fired heat pump water heaters
Windows	• Replacing all windows with next-generation triple-pane windows

Findings

This study confirmed that the economics of gas and electric heating technologies will likely depend on regional fuel pricing for the foreseeable future. Results from the work also informed the aspirational performance and cost targets, which are published in NRCan's 2017 Market transformation strategies for energy-using equipment in the building sector.

Model validation and testing of HOT2000* version 11 with the ANSI/ASHRAE standard

Description

Natural Resources Canada (NRCan) develops, distributes and supports the HOT2000 residential energy simulation program. The HOT2000 energy analysis program is an integral part of delivering energy efficiency initiatives for new and existing houses. It is a key component of provincial and federal energy rating, labelling and incentive programs. It provides calculations for building performance code compliance and is used by design professionals and builders to improve residential housing design.

Recently, the *National Building Code of Canada* (NBC) has undergone a review with the release of the 2015 version. When it was updated in 2012, it included, for the first time, prescriptive requirements for the minimum energy performance of Canadian houses and also provided a performance pathway.

The performance pathway requires that the builder demonstrate that the house uses less energy than a reference house constructed to the prescriptive requirements. The builder may use any software tool for the performance pathway calculations, provided that tool has been tested by using the ASHRAE 140 standard. To ensure that the performance pathway for residential houses in the 2015 NBC is a viable option, NRCan tested HOT2000 to the ASHRAE 140 test standard.

The main objective of this project was to test, validate and report findings of HOT2000 version 11 with methods described in ASHRAE standard 140-2014.

Findings

Based on the standardized gigajoule scale, the EnerGuide Rating System introduced changes that required comprehensive validation and testing of HOT2000, as per ASHRAE standard 140-2014. The Class I tests from the standard assess algorithms, while the Class II tests focus on whole building energy analysis including HERS BESTEST and, more relevantly, ground-coupling for basement foundations.

HOT2000 results compared very well in 17 out of 20 test cases dealing with space heating analysis, with the exception of heavy thermal mass coupled with higher solar gains. The cooling load analyses of HOT2000 for Class II were close to those of reference software, with the exception of a case with large solar gains caused by all south-facing windows. Overall, HOT2000 version 11 meets, and in some cases exceeds, the energy performance requirements for low-rise residential buildings built as per the NBC Part IX.

*HOT2000 is an official mark of Natural Resources Canada.

House as a system

Status: Final report available

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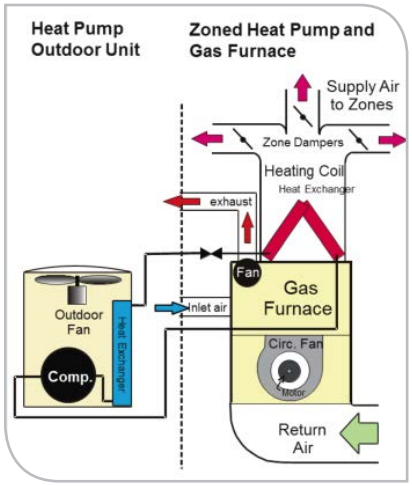

Mechanical systems

Status: Final report available March 2018

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Hybrid (dual-fuel) heating systems

Description

CanmetENERGY-Ottawa is working with Enbridge Gas Distribution Inc. and MaRS to explore the technical potential of next-generation hybrid heating technology that combines gas-fired heating systems with electric heat pumps.

Key advantages of hybrid heating systems	
In contrast to conventional gas-fired furnaces	• Lower overall energy use • Lower operating costs
In contrast to electric heat pumps	• Improved cold-weather comfort • Lower operating costs • Reduced impact on the electric utility

In this project, researchers at CanmetENERGY-Ottawa mapped data about heat pump performance to heating loads from new and existing housing in five Ontario municipalities. Initial findings show that hybrid heating systems can dramatically reduce gas consumption and greenhouse gas emissions. At the same time, they protect homeowners from the added expense of operating electric backup heating and minimize the home's contribution to winter peak heating loads.

In the next phase of this project, CanmetENERGY-Ottawa will collaborate with utilities and manufacturers to develop optimum hybrid design strategies and to identify key challenges to commercializing this technology.

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