# RESEARCH HIGHLIGHT

# Energy Performance Modelling of Energy Efficiency Retrofits in Northern Housing

May 2015 Technical Series

## INTRODUCTION

Northern communities of Canada have long relied predominately on fossil fuels for heat and electricity. While information on ways to conserve energy in Canadian homes is readily available, research into energy efficiency retrofits within the context of northern climate and housing types is more limited. To help characterize the extent of energy efficiency measures (EEMs) that would have to be applied to attain specific levels of energy consumption reduction, CMHC supported research to evaluate three representative housing archetypes, in five Northern Canadian communities. The scope of EEMs included building envelope (the addition of insulation, improved windows and airtightness), mechanical equipment (improved combustion and electrical use efficiency), lighting fixtures (improved efficacy) and electric appliances (higher efficiency). Energy savings at both the system/ equipment and whole-building levels were generated for each EEM. From these results, packages of EEMs were customized to deliver whole-building energy savings of 10% and 25% for each housing archetype in each location. Given that electricity and fossil fuel costs can vary significantly with time and location, the cost savings associated with the EEM packages were not examined in the study. However, the energy savings can be used in combination with local knowledge of energy costs to assess the paybacks or return on investments that the EEMs represent.

## METHODOLOGY

Five locations were selected to provide a range of weather conditions that would be recognizable in many Northern communities: Chesterfield Inlet, Cambridge Bay and Resolute of Nunavut; Dawson of the Yukon Territory; and Inuvik of the Northwest Territories.

**Table 1** Climate Data From HOT2000 for Selected Locations

| Location | Latitude | Annual HDD (18°C) | Average Wind Speed (km/hr) |
|---|---|---|---|
| Dawson, Y.T. | 64.5° | 8,400 | 5.1 |
| Inuvik, N.W.T. | 68.3° | 10,050 | 9.8 |
| Cambridge Bay, Nun. | 68.8° | 10,800 | 20 |
| Chesterfield, Nun. | 64.3° | 11,000 | 20 |
| Resolute, Nun. | 74.7° | 12,600 | 21 |

Discussion with Northern housing corporations (Nunavut and N.W.T.) and CMHC established three reference housing archetypes for analysis; a one-storey, three-bedroom, cathedral-style bungalow (N1S), a two-storey, three-bedroom home (N2S) and a two-storey multi-unit building comprising of 4 three-bedroom units (NMU). Insulation levels were taken from available architectural drawings, as provided by the housing corporations, while the airtightness of the houses was supported from a background study undertaken by SAR Engineering on Canadian housing in 2004.

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In analyzing the impact of EEMs on whole-building energy consumption, it was first useful to break down the whole-building energy consumption and identify end-use energy consumption for the reference archetype houses. Allowing for differences in climate, fuel type, and building type, a range for each end-use, is shown in figure 1.

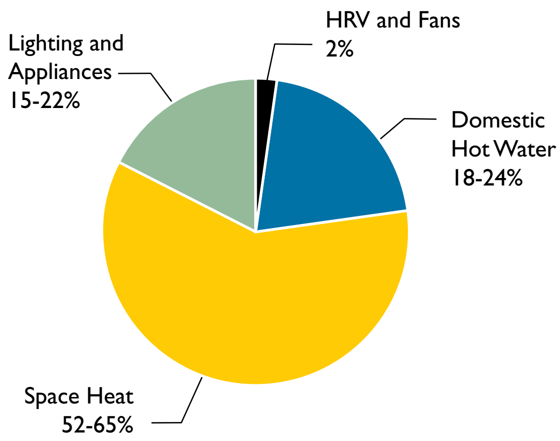


**Figure 1** Northern Housing Archetype Annual Energy End-Use Consumption Breakdown

Once the models for the reference houses were established, EEMs for each system were developed based on available energy-efficient housing reference standards and guidelines (such as R-2000 and Passive House), ENERGY STAR® certified products and market best products as sourced from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) product directory.[1] Table 2 outlines all of the EEMs used in the study.

HOT2000 version 10.5.1 was used to run the simulations for the reference houses and the same houses with both singular and combinations of EEMs. Results from individual EEM runs were then used to develop packaged runs delivering the desired 10% and 25% whole-building energy savings. Packages were bundled with consideration given toward practical solutions that could be delivered in the Northern communities. For all cases, equipment EEMs were given priority as they represent easily implemented measures that also offered minimal occupant disruption.

When equipment EEMs alone were not sufficient to attain a 25% improvement in whole-building energy consumption, envelope EEMs were then added. Envelope EEMs were bundled with the assumption that airtightness and insulation would be addressed in tandem. Moderate levels in the improvement of airtightness were viewed as being most realistic for northern housing and were subsequently given higher priority when developing the retrofit packages. The addition of insulation to the attic space in row housing was given priority for piecewise insulation retrofits as cost and occupant disruption were expected to be lower; the addition of insulation within accessible crawl spaces in all archetypes was also favoured on the same merit.

The impact of individual EEMs on whole-building energy savings are summarized in table 2 for the three building types in the five communities.

## Equipment energy efficiency improvements

As space heating represents up to two thirds of total annual energy consumption (as shown in figure 1), EEMs that affect space heating were found to offer the greatest potential for savings. An oil furnace retrofit sees the largest potential savings (up to 28% for a two-storey residence in Cambridge Bay or Resolute). Gas furnace retrofits (Inuvik) offer less savings than oil furnace retrofits, as opportunities for improvements in seasonal efficiency for gas appliances are less significant (80% to 98% for gas appliances versus 71% to 95% for oil appliances). Incremental gains from high-efficiency to "best case efficiency" furnaces are marginal at 2%-2.5% for oil and 1% for natural gas. The greatest savings for furnace retrofits are achieved in the colder climates of Resolute, Chesterfield Inlet and Cambridge Bay, 4% to 6% greater than Inuvik and Dawson.

Domestic water heaters displayed greater retrofit savings (3%-4%) in natural gas-fired products over oil due to greater relative improvements in energy factors for the gas-fired appliances listed in the AHRI directory. The directory did not list any tankless oil products, so only tankless gas systems were modelled for best case energy efficiency improvements which resulted in further savings of up to 1%.

[1] Air-Conditioning, Heating and Refrigeration Institute (2012). Directory of Certified Product Performance. Retrieved from: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

**Table 2** Summary of Whole-Building Annual Energy Consumption Savings by Individual EEMs

| | | Win | AT Mod | AT R-2000 | AT PH | R-10 R/C | R-20 R/C | R-10 W | R-20 W | R-10 F |
|---|---|---|---|---|---|---|---|---|---|---|
| | **EEM Description** | Triple-glazed, low-e, argon-filled, 1.20 W/m²·K | 3.16 $ACH_{50}$ | 1.5 $ACH_{50}$ | 0.6 $ACH_{50}$ | + R-10 (RSI-1.76) Nominal Insulation | + R-20 (RSI-3.52) Nominal Insulation | + R-10 (RSI-1.76) Nominal Insulation | + R-20 (RSI-3.52) Nominal Insulation | + R-10 (RSI-1.76) Nominal Insulation |
| **NIS** | Dawson | 6.9% | 5.6% | 8.6% | 8.5% | 0.9% | 1.7% | 3.4% | 5.2% | 1.4% |
| | Inuvik | 6.6% | 6.2% | 9.2% | 9.2% | 1.0% | 1.7% | 3.5% | 5.4% | 1.5% |
| | Cambridge | 6.4% | 9.2% | 15.6% | 17.0% | 1.0% | 1.7% | 3.6% | 5.5% | 1.6% |
| | Chesterfield | 6.3% | 7.7% | 15.8% | 17.3% | 0.9% | 1.6% | 3.6% | 5.4% | 1.5% |
| | Resolute | 6.8% | 9.1% | 17.9% | 19.3% | 1.0% | 1.6% | 3.5% | 5.4% | 1.5% |
| **N2S** | Dawson | 6.6% | 8.6% | 13.6% | 14.7% | 0.7% | 1.2% | 1.9% | 3.2% | 0.8% |
| | Inuvik | 6.1% | 9.2% | 14.0% | 15.7% | 0.7% | 1.2% | 1.9% | 3.1% | 0.8% |
| | Cambridge | 6.4% | 12.2% | 20.7% | 23.7% | 0.7% | 1.2% | 2.1% | 3.4% | 0.9% |
| | Chesterfield | 6.0% | 12.0% | 20.4% | 23.4% | 0.8% | 1.2% | 2.0% | 3.2% | 0.9% |
| | Resolute | 6.4% | 12.2% | 20.5% | 23.5% | 0.7% | 1.2% | 2.0% | 3.3% | 0.9% |
| **NMU** | Dawson | 6.9% | 0.7% | 4.9% | 4.3% | 1.8% | 2.9% | 0.4% | 0.6% | 1.7% |
| | Inuvik | 6.9% | 0.7% | 5.9% | 5.2% | 1.8% | 2.9% | 0.4% | 0.7% | 1.8% |
| | Cambridge | 6.4% | 3.0% | 11.6% | 12.8% | 1.7% | 2.8% | 0.4% | 0.6% | 1.7% |
| | Chesterfield | 6.2% | 3.7% | 12.0% | 13.3% | 1.6% | 2.7% | 0.4% | 0.7% | 1.6% |
| | Resolute | 6.4% | 3.1% | 11.6% | 12.7% | 1.7% | 2.8% | 0.4% | 0.7% | 1.7% |

| | | R-20 F | R-10 All | R-20 All | Furnace High Eff | Furnace Best | E-Star Light and App | DHW High EF | DHW Best |
|---|---|---|---|---|---|---|---|---|---|
| | **EEM Description** | + R-20 (RSI-3.52) Nominal Insulation | + R-10 (RSI-1.76) Nominal Insulation | + R-20 (RSI-3.52) Nominal Insulation | Oil: 92% Gas: 95% | Oil: 96% Gas: 98% | 39% reduction of kWh | Oil: 63% Gas: 90% | Oil: n/a Gas: 98% |
| **NIS** | Dawson | 2.3% | 5.7% | 9.1% | 17.7% | 19.8% | 10.2% | 3.2% | - |
| | Inuvik | 2.5% | 5.9% | 9.4% | 9.7% | 10.8% | 10.2% | 7.1% | 8.0% |
| | Cambridge | 2.6% | 6.1% | 9.7% | 25.1% | 27.7% | 7.0% | 2.3% | - |
| | Chesterfield | 2.5% | 5.9% | 9.4% | 25.0% | 27.5% | 7.4% | 2.4% | - |
| | Resolute | 2.5% | 6.0% | 9.5% | 25.1% | 27.8% | 6.3% | 2.2% | - |
| **N2S** | Dawson | 1.4% | 3.4% | 5.7% | 17.3% | 19.6% | 10.1% | 3.2% | - |
| | Inuvik | 1.4% | 3.6% | 5.8% | 9.6% | 10.6% | 9.9% | 6.9% | 7.8% |
| | Cambridge | 1.6% | 3.7% | 6.0% | 25.5% | 28.3% | 6.7% | 2.2% | - |
| | Chesterfield | 1.5% | 3.5% | 5.8% | 25.4% | 27.8% | 7.0% | 2.3% | - |
| | Resolute | 1.5% | 3.5% | 6.0% | 25.4% | 28.3% | 6.1% | 2.1% | - |
| **NMU** | Dawson | 2.9% | 4.0% | 6.5% | 14.9% | 17.3% | 7.3% | 3.1% | - |
| | Inuvik | 3.0% | 3.9% | 6.5% | 11.5% | 12.7% | 6.8% | 6.2% | 6.6% |
| | Cambridge | 2.8% | 3.8% | 6.2% | 17.2% | 20.0% | 5.0% | 2.3% | - |
| | Chesterfield | 2.8% | 3.7% | 6.1% | 17.3% | 20.1% | 5.2% | 2.4% | - |
| | Resolute | 2.8% | 3.8% | 6.2% | 17.3% | 20.2% | 4.6% | 2.3% | - |

**Abbreviations:**
AT=Airtightness, Mod=Moderate, R-2000 Standard, PH=Passive House, R/C = Roof/Ceiling, W=Wall, F=Floor, Eff=Efficiency, App=Appliances, EF=Energy Factor, DHW=Domestic Hot Water

## Airtightness

Reducing the air leakage of the building envelope offers the second best whole-building energy savings. A two-storey, detached house, in Cambridge Bay can see 24% savings with a Passive House level of airtightness retrofit (that is, reducing the air leakage from 4.7 $ACH_{50}$ to 0.6 $ACH_{50}$). A ventilation check was performed for all levels of airtightness and archetypes to confirm if a HRV was required to meet ASHRAE 62.1.[2] Airtightness EEMs show a large range of savings, depending on location, housing type and HRV requirement. The following are some of the important observations related to airtightness EEMs:

- Savings for row housing are less than detached housing types given the lower ratio of envelope surface area to building volume.
- The need to install HRVs to ensure adequate ventilation after air sealing the row housing to moderate airtightness (3.6 $ACH_{50}$) substantially reduces savings, as the improvements in airtightness performance (4.7 $ACH_{50}$ to 3.16 $ACH_{50}$) are largely offset by HRV energy consumption.
- Savings increase with each successive improvement to airtightness for Chesterfield, Resolute and Cambridge Bay (referred to as "Chest" in figure 2) for all archetypes.
- Savings are lower for all housing types in Inuvik and Dawson (referred to as "Daw" in figure 2) and as the envelope is tightened, the incremental savings are also less than those for houses located in colder climates.
- Row housing types in Inuvik and Dawson exhibit drops in energy savings from R-2000 to the Passive House standard. This is due to the greater HRV-supplied ventilation needed to meet ASHRAE 62.1, thereby consuming more energy than what is saved by implementing airtightness improvements.

Recognizing the distinct weather attributes among the communities helps to further explain the differences in results. Inuvik and Dawson both experience the fewest heating degree days and, more importantly, considerably lower wind speeds than the other three sites (see table 1). Consequently, the envelope temperature gradient, wind-induced indoor-outdoor air leakage and wind-washing effects are reduced, which diminishes the net benefit of improving airtightness (from an energy-saving perspective alone) in Dawson and Inuvik.

Figure 2 demonstrates the differences found between communities of significantly different climates. Lower realized savings, lower rate of savings per unit airtightness improvement, and a less airtight point of inflection (point where savings begin to diminish) are all exhibited by the Dawson archetype plots versus Chesterfield.

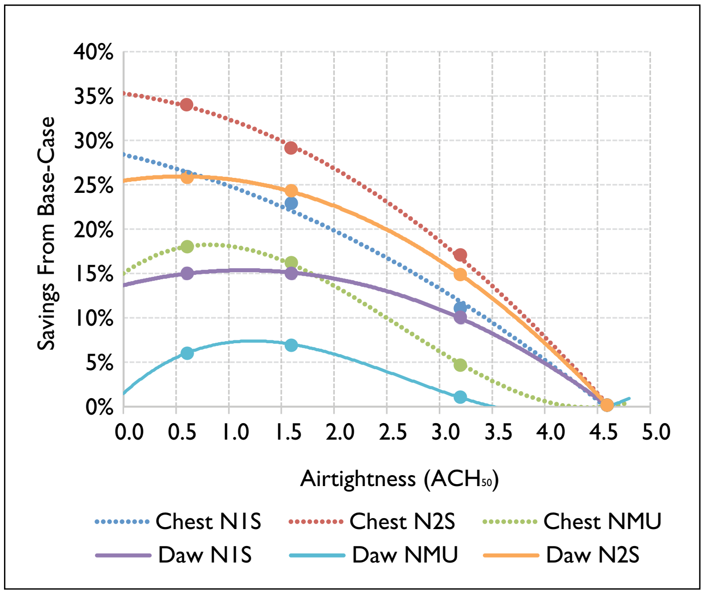


**Figure 2** Airtightness Savings Return for Chesterfield and Dawson Housing Types

2 ASHRAE 62.1-2010, Ventilation for Acceptable Indoor Air Quality © 2010, American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, Georgia.

## ENERGY STAR® appliances and lighting

Savings from available ENERGY STAR® appliances and lighting, over reference 2010 statistics for average Canadian homes, revealed annual electrical energy savings of 39%.[3,4] From a whole-building perspective, this translates to a 5%-10% savings. Interactive effects were found to be present with ENERGY STAR® lighting and appliance retrofits. More efficient lighting provides less internal heat gain, requiring additional space heat from the furnace to meet demand. The observed effect saw an erosion of approximately 25% of the expected savings. Interactive effects were also investigated for other EEMs, such as furnace and hot water, but those effects were observed to be negligible.

## Insulation

Individual insulation EEMs applied to the wall, floor or roof/ceiling were observed to offer the least whole-building energy savings; in some cases less than 1%. Differences in savings between housing types and envelope components can be attributed to different building geometries and baseline insulation design values. For instance, in detached homes, walls offer the largest surface area to insulate, which translates to greatest savings. However, for multi-unit row housing, floors and roof/ceilings represent a larger proportion of the total envelope area and therefore offer more savings. Addition of RSI-1.76 (R-10) insulation to the entire building envelope results in 3.5%-6% energy savings. Improving the reference house thermal values by adding RSI-3.52 (R-20) insulation throughout saves between 5.5% and 9.5% of whole-building energy.

## ENERGY STAR® windows

Retrofitting windows from clear double-glazed to low-e, triple-glazed units had a substantial effect on the houses modelled. Whole-building energy savings of 6%-7% are observed from the window EEMs. These savings are similar to that of adding RSI-3.52 (R-20) insulation throughout the entire envelope. While the window-to-wall ratio is quite low for the northern archetypes (6%-11%), the benefits of ENERGY STAR® windows are still significant and highlight the importance of addressing the weakest thermal links (lowest RSI) in the envelope. Although the cost of replacing windows is high in comparison to the cost of insulation, the installation is simpler and often less disruptive for the occupants; especially when considering the complications associated with adding insulation to existing wall assemblies. The window replacement EEM is attractive especially when failed or damaged windows are due for renewal.

## EEM packages

For the development of EEM packages, the five locations were divided into three groups based upon climate and whole-building EEM energy savings profiles. Dawson and Inuvik stood out as unique individual cases on account of differences in climate and heating fuel type. Chesterfield Inlet, Cambridge Bay and Resolute were grouped together based on their similar climates. Cambridge Bay was used as the basis in this third grouping as it best represented the average energy saving profile of the three communities. Packages of EEMs that offered two levels of savings, 10% and 25%, were simulated in HOT2000 version 10.5.1. Practical measures that limited disruption to occupants were given preference. The results of the proposed packages are presented in tables 3-5. For each location, packages of EEMs attaining a 10% whole-building energy savings are provided first, followed by packages of EEMs attaining a 25% whole-building energy savings.

[3] The Office of Energy Efficiency at Natural Resources Canada (2010). Energy Use Data Handbook Tables – Residential Sector, Table 15. Retrieved from: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/handbook/handbook_res_00.cfm

[4] The Office of Energy Efficiency at Natural Resources Canada (2010). ENERGY STAR® Searchable Product List. Retrieved from: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?language_langue=en&action=app%2Ewelcome-bienvenue&attr=0

Dawson, with the warmest climate (fewest heating degree-days), benefits most from the electrical EEMs as they contribute a greater portion of overall building consumption for that location. Space-heat envelope EEMs offer lower relative savings for Dawson. A 25% savings cannot be met through envelope EEMs alone and must be bundled with multiple equipment EEMs as shown in packages G through I. Savings of 23% can be achieved from equipment EEMs (package E) for one- and two-storey dwelling units while 25% can be achieved for all house types through an envelope/equipment package of window and high-efficiency furnace EEMs (package F).

**Table 3a** EEM Packages Attaining 10% Whole-Building Energy Savings for Dawson

| Location/Package | | House Type | Win | AT Mod | R-20 All | E-Star Light and App | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|
| DAWSON (10%) | A | One- and Two-Storey | | | | ✓ | | 11% |
| | B | Multi-Unit | ✓ | | | ✓ | | 10% |
| | C | One- and Two-Storey | | ✓ | ✓ | | | 14%[1] |
| | D | All | ✓ | | | | ✓ | 10% |

[1] To meet same level of savings, 14%, a multi-unit housing type would need R-2000 tightness. If ceiling/roof insulation is an issue then with just floor and wall insulation the one- and two-storey housing types see 10% savings.

**Table 3b** EEM Packages Attaining 25% Whole-Building Energy Savings for Dawson

| Location/Package | | House Type | Win | AT R-2000 | R-20 All | Furnace High Eff | E-Star Light and App | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|---|
| DAWSON (25%) | E | One- and Two-Storey | | | | ✓ | ✓ | ✓ | 23%[1] |
| | F | All | ✓ | | | ✓ | | | 25%[2] |
| | G | One- and Two-Storey | | ✓ | ✓ | | | ✓ | 22%[3] |
| | H | One- and Two-Storey | ✓ | ✓ | ✓ | | | | 25%[4] |
| | I | Multi-Unit | ✓ | ✓ | ✓ | | ✓ | | 25% |

[1] Multi-unit housing requires this package with a best furnace upgrade to realize 20% savings.
[2] Multi-unit housing requires best furnace upgrade for same savings (25%).
[3] Same savings realized if DHW High EF replaced with E-Star EEM. Multi-unit sees 15% savings from same package.
[4] Multi-unit housing types see 18% savings from same package.

Inuvik sees 10% savings from a stand-alone furnace EEM (package C) or through combinations of equipment and less disruptive envelope EEMs. An Inuvik row house offers a quick, non-invasive 10% savings in package E. No single EEM can provide 25% savings for Inuvik, however various combinations of equipment and envelope EEMs do achieve pathways to this level of savings.

**Table 4a** EEM Packages Attaining 10% Whole-Building Energy Savings for Inuvik

| Location/ Package | | House Type | Win | AT Mod | R-20 R/C | R-20 All | Furnace High Eff | E-Star Light and App | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| INUVIK (10%) | A | One- and Two-Storey | | ✓ | | ✓ | | | | 15%[1] |
| | B | All | | | | | | ✓ | ✓ | 10-13%[2] |
| | C | All | | | | | ✓ | | | 11-13%[3] |
| | D | All | ✓ | | | | | ✓ | | 10-12% |
| | E | Multi-Unit | | | ✓ | | | | ✓ | 9% |

[1] Multi-unit housing type requires R-2000 tightness to provide >10% savings (12%). With moderate tightness the savings are 7.5%.
[2] Multi-unit gives 10% savings while detached offers 13%.
[3] Multi-unit gives 13% savings while detached offers 11%.

**Table 4b** EEM Packages Attaining 25% Whole-Building Energy Savings for Inuvik

| Location/ Package | | House Type | Win | AT Mod | AT R-2000 | R-20 All | Furnace High Eff | E-Star Light and App | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| INUVIK (25%) | F | One- and Two-Storey | | ✓ | | ✓ | ✓ | | | 25%[1] |
| | G | One- and Two-Storey | ✓ | ✓ | | ✓ | | | ✓ | 28% |
| | H | All | ✓ | | | | ✓ | ✓ | ✓ | 25% |
| | I | One- and Two-Storey | | | ✓ | ✓ | | | ✓ | 26%[2] |
| | J | Multi-Unit | | | ✓ | ✓ | ✓ | | | 24% |

[1] Multi-unit gives 19% savings with same package.
[2] Multi-unit gives 19% savings with same package.

The remaining group, comprising Chesterfield, Cambridge Bay and Resolute, benefit highly from space-heat related EEMs like envelope and furnaces. This is the only group where significant envelope EEMs or stand-alone furnace EEMs contribute towards 25% savings (packages E-G).

**Table 5a** EEM Packages Attaining 10% Whole-Building Energy Savings for Chesterfield, Cambridge Bay and Resolute Group

| Location/Package | | House Type | Win | AT Mod | R-20 R/C | R-20 F | E-Star Light and App | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|---|
| CHEST, CB, and RES (10%) | A | All | ✓ | | | | | ✓ | 9% |
| | B | All | ✓ | | | | ✓ | | 10% |
| | C | One- and Two-Storey | | ✓ | | | | | 8-12%[1] |
| | D | Multi-Unit | ✓ | | ✓ | ✓ | | | 12% |

[1] One-storey housing type exhibits 8-9% savings while two-storey is 12%.

**Table 5b** EEM Packages Attaining 25% Whole-Building Energy Savings for Chesterfield, Cambridge Bay and Resolute Group

| Location/ Package | | House Type | Win | AT Mod | AT R-2000 | R-20 All | Furnace High Eff | Furnace Best | DHW High EF | Package Savings (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| CHEST, CB, and RES (25%) | E | One- and Two-Storey | ✓ | ✓ | | ✓ | | | | 23%[1] |
| | F | One- and Two-Storey | | | | | ✓ | | | 25%[2] |
| | G | One- and Two-Storey | | | ✓ | ✓ | | | | 25-27%[3] |
| | H | One- and Two-Storey | ✓ | ✓ | | ✓ | | | ✓ | 25-27%[4] |
| | I | Multi-Unit | ✓ | | | | | ✓ | | 26%[5] |

[1] Multi-unit gives 15% savings, needs R-2000 tightness for equivalent savings.
[2] Multi-unit gives 17% savings.
[3] One-storey has 25% savings while two-storey slightly better at 27%. Multi-unit gives 18% savings.
[4] One-storey has 27% while two-storey slightly lower at 25%. Multi-unit gives 19% savings, needs R-2000 tightness for equivalent savings.
[5] Package with high-efficiency furnace yields 23%-24% savings.

The energy efficiency measures had different levels of benefit to the various communities depending on archetype, climate and available fuel type. The following table summarize EEMs that are pertinent to each instance.

**Table 6** Summary of most relevant EEMs per Location/Archetype

| Archetype | Dawson | Inuvik | Chesterfield/Resolute/ Cambridge Bay |
|---|---|---|---|
| One-Storey (N1S) | ▪ Furnace – High Eff or Best<br>▪ E-Star Light and Appliance<br>▪ Insulation Walls or All | ▪ DHW – High EF<br>▪ E-Star Light and Appliance<br>▪ Insulation Walls or All | ▪ Furnace – High Eff or Best<br>▪ R-2000 Airtightness<br>▪ Insulation Walls or All |
| Two-Storey (N2S) | ▪ Furnace – High Eff or Best<br>▪ E-Star Light and Appliance<br>▪ R-2000 Airtightness | ▪ DHW – High EF<br>▪ E-Star Light and Appliance | ▪ Furnace – High Eff or Best<br>▪ R-2000 Airtightness |
| Multi-Unit Row Housing (NMU) | ▪ Furnace – High Eff or Best<br>▪ E-Star Light and Appliance<br>▪ Insulation Roof/Ceiling or Floor | ▪ DHW – High EF<br>▪ E-Star Light and Appliance<br>▪ Insulation Roof/Ceiling or Floor | ▪ Furnace – High Eff or Best<br>▪ R-2000 Airtightness<br>▪ Insulation Roof/Ceiling or Floor |

From the results and analysis of this study, Northern housing corporations and industry can draw several recommendations to improve whole-building energy use in existing housing. Airtightness and oil furnace retrofits offer the greatest savings (15%-28%) for all communities and archetypes. Secondary measures include triple-glazed, low-e windows, and ENERGY STAR® lighting and appliance retrofits which provide 6%-10% whole-building savings. Piecewise insulation EEMs offer the least savings but a full insulation retrofit is more attractive and can be paired with building envelope renovations and airtightness improvements to reduce cost.

## Implications for the northern housing industry

This research study provides an indication of the extent of the energy efficiency measures needed to make notable reductions in the energy consumption of northern housing. With local knowledge of energy and retrofit costs, preliminary estimates of the energy cost savings and paybacks associated with the energy efficiency measures can be developed. The study also demonstrates interactive effects within some of the proposed EEMs. Examples of these effects include savings from efficient lighting and increased airtightness being partially offset by greater space heating and ventilation requirements. In either case, while the savings may be less than expected, the measures are often warranted for other reasons including ensuring energy use is as efficient as possible at each end-use point, enhancing the indoor living environment and increasing the durability of the building envelope. With the variety of EEM packages offered, a residential energy consumption simulation program is presented that explores the energy retrofit potential of archetypical housing in the North.

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