Market transformation strategies for energy-using equipment in the building sector

Supporting the transition to a low-carbon economy

Energy and Mines Ministers' Conference

St. Andrews by-the-Sea, New Brunswick

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EXECUTIVE SUMMARY

The *Pan-Canadian Framework on Clean Growth* and *Climate Change* outlines the commitments of the federal, provincial and territorial governments (Governments) to reduce greenhouse gas emissions and promote clean, low-carbon economic growth for Canadians. Speeding up the development and mainstream adoption of clean and more energy-efficient equipment technologies is a key component to achieving these goals for Canadians.

Residential and commercial buildings account for 17% of total greenhouse gas emissions in Canada. For this reason, the Pan-Canadian Framework outlines a building strategy with measures to improve energy performance of new and existing buildings through codes and labels and set new standards for energy-using equipment.

Market transformation requires a series of strategic interventions designed to overcome barriers to the adoption of new technologies, with a view to accelerating market uptake. As part of the shared priorities identified during the Energy and Mines Ministers' Conference, Governments are focusing collaborative efforts on market transformation in three equipment areas, based on their current energy use and potential to reduce greenhouse gas emissions:

- **Residential windows** – They account for up to 35% of home heat losses, and if today's best technology were deployed broadly, total home energy use could be reduced by 9% and greenhouse gas emissions lowered by more than 5 megatonnes.

- **Space heating** – It represents 56% to 64% of the energy use in homes and buildings, and if today's best technology were deployed broadly, total home energy use could be reduced by 30% and greenhouse gas emissions lowered by 18 megatonnes.

- **Water heating –** It represents 8 to 19% of the energy use in homes and buildings, and if today's best technology were deployed broadly, total home energy use could be reduced by 5% and greenhouse gas emissions lowered by more than 3 megatonnes.

This report outlines the Governments' aspirational goals over the short, medium and long term for ambitious but achievable energy performance levels for residential windows, space heating and water heating equipment. The goals support the broader objectives of the Pan-Canadian Framework—to reduce greenhouse gas emissions, promote adoption and support clean technology innovation, and to ultimately shift to a low-carbon economy. The report also identifies key barriers to market adoption for each equipment area and measures to overcome them.

This report will serve as a basis to guide stakeholder engagement toward the development of detailed road maps to achieve the aspirational goals, as well as to establish performance indicators to measure and report to ministers on progress each year.

MARKET TRANSFORMATION STRATEGY OVERVIEW

LONG-TERM ASPIRATIONAL GOALS

Long-term goals are supported by short- and medium-term aspirational goals.

- High-performance, next-generation residential windows are standard in Canada.
  - **Performance target:** All residential windows for sale meet a U-factor of 0.8 by 2030.
- Heat pumps (or equipment with equivalent performance) are standard for residential and commercial space and water heating in Canada.
  - **Performance targets:** All space and water heating technologies for sale meet an energy performance of more than 100% by 2035.

MARKET BARRIERS

- **Availability**
  Technologies are not yet fully commercialized or available in Canada.
- **Accessibility**
  There is insufficient product choice in the market, and current performance testing is not aligned with product functionality and capabilities.
- **Awareness**
  Contractors, building owners, designers, and engineering firms are unfamiliar with the benefits of the technology and do not have the expertise to design, install and service them or have not yet been convinced of its merits.
- **Affordability**
  High upfront costs, installation and/or maintenance costs deter market demand.
- **Acceptance**
  Form, fit, and function of the technologies are not well accepted or deemed too risky by end users.

MEASURES

- Integrate research and development performance and cost targets into federal funding priorities.
- Create and update testing standards to rate energy performance of emerging technologies.
- Undertake field projects with partners to demonstrate proof of concept and longer-term performance of emerging technologies.
- Develop, disseminate and share case studies and best practices.
- Build capacity through trades and other programs for quality installation and maintenance.
- Consider aligning ENERGY STAR levels with aspirational goals.
- Encourage demand through financial incentives aligned with aspirational goals.
- Consider supply-side incentives to build Canadian capacity for manufacturing innovative technologies.
- Identify partnerships with other jurisdictions (e.g. U.S. states) to drive scale-up in the market.
- Consider federal and/or provincial regulations that harmonize standards across Canada.

OUTCOMES

- Sustained and ongoing reductions in greenhouse gas emissions.
- Canadians have access to high-performance technologies that are cost–effective and operate reliably in Canada's climate.
- Research and development investments support emerging technologies.
- Canada has strong contractor expertise and a strong manufacturer base to supply, install and maintain the technologies.
- Canadian manufacturers have new international growth opportunities.
- Codes and standards are mutually supportive and harmonized and provide a level playing field across Canada.

INTRODUCTION

Markets are dynamic - new products are introduced regularly, consumer demands change, and prices fluctuate continuously. Markets can move independently toward high-efficiency technologies that provide improved economic and environmental outcomes. But occasionally, barriers prevent the market from achieving an energy efficiency objective.

There are many reasons why markets resist change; for example, unfamiliarity with a new technology, difficulty finding it or a high initial purchase price. There are examples where more efficient technologies were introduced in the market, but the response was not positive due, for example, to lack of understanding or perceived poor performance relative to existing products. Technologies that have not yet reached, or are struggling to reach, their full potential could benefit from market transformation.

Market transformation is a series of strategic interventions to cause lasting changes in the structure or function of a market or in the behaviour of participants, to accelerate the adoption of new technologies. Governments play a key role in market transformation because they have access to tools, levers and resources that can address barriers that markets cannot overcome on their own; for example, financing research and development, implementing certification schemes or developing regulations. Measures typically focus on making a technology available, accessible and affordable, and ensuring market players are aware it exists and accept its form, fit, and function.

Market transformation is an important component of the *Pan-Canadian Framework on Clean Growth and Climate Change* and Canada's long-term transition to a low-carbon economy. Under the Pan-Canadian Framework, Governments have committed to reducing greenhouse gas emissions and promoting clean, low-carbon economic growth for Canadians. Residential and commercial buildings are a key part of the Framework as the building sector is responsible for 17% of total greenhouse gas emissions in Canada.

The five A's of market transformation

- **Availability:** Does the technology exist?
- **Accessibility:** Does the market have access to the technology?
- **Awareness:** Does the market know about the technology?
- **Affordability:** Is the technology affordable?
- **Acceptance:** Is the form, fit, and function of the technology acceptable?

One component of the Framework's plan to reduce greenhouse gas emissions in the building sector is to improve the energy performance of equipment. This would be accomplished by setting new standards for heating equipment and other key technologies to the highest level of efficiency that is economically and technically achievable. Governments would start by sending an early signal about expected future performance levels, in order to support long-term market transformation efforts and motivate markets to accelerate the uptake of these targeted technologies in advance of anticipated standards.

Market transformation was identified as a priority by Governments under the Energy and Mines Ministers' Conference (EMMC) *Framework and Action Plan for Collaboration on Energy Efficiency Standards*.[1] Under EMMC, and in line with the Canadian Energy Strategy, Governments agreed to set aspirational goals for energy performance in the following three equipment areas, where new high-efficiency technologies could generate significant energy savings and greenhouse gas emissions reductions, but where there are barriers to market adoption.[2]

1 http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Encouraging%20Market%20Transformation_access_eng.pdf

2 Estimated greenhouse gas emissions reductions are a maximum average annual "potential" for residential applications only. These are not additive, as they do not account for interactive effects.

WINDOWS	SPACE HEATING	WATER HEATING
Account for up to 35% of the heat loss from a home's envelope.	Represents 56% to 64% of energy use in homes and buildings, the largest source of direct sector emissions.	Represents 8% to 19% of energy use in homes and buildings.
If all residential windows were replaced with next-generation technology (U-factor of 0.8) today: ▪ Total home energy use would decrease by 9%. ▪ Greenhouse gas emissions would be reduced by more than 5 Mt.	If all residential heating systems were replaced with heat pump technology today: ▪ Total home energy use would decrease by 30%. ▪ Greenhouse gas emissions would be reduced by 18 Mt.	If all residential water heating systems were replaced with heat pump technology today: ▪ Total home energy use would decrease by 5%. ▪ Greenhouse gas emissions would be reduced by more than 3 Mt.

Increased performance and design of residential windows, space heating and water heating will also encourage and complement planned updates to codes for new and existing homes and buildings.

PURPOSE

The purpose of this report is to outline Governments' agreed-upon short-, medium- and long-term aspirational goals for residential windows, space heating and water heating. The intent is to send a clear market signal about the direction and level of ambition for energy performance in these equipment areas, coupled with an identification of key market barriers and proposed measures to overcome them. The desired outcome is to put in place a framework that will guide engagement with stakeholders to develop detailed road maps and measures to reach the aspirational goals.

To develop this report, a series of stakeholder workshops was held in March 2017. Participants included manufacturers, gas and electric utilities, industry associations, advocates, and building code developers. Their input was used to identify the key market barriers included in this report.

Governments have successfully transformed markets in the past; A case study of residential natural gas furnaces in Canada

Today's furnaces are much more efficient than their predecessors due to a combination of innovation and measures to broadly deploy them into over 5 million Canadian households that heat with natural gas. Furnaces now available on the Canadian marketplace are among the most efficient in the world.

In the wake of the energy crises of the 1970s, Canadians actively sought new technologies to reduce their rapidly growing energy bills. At the same time there were also safety concerns with the standard atmospherically vented furnaces of the day, which could leak poisonous gases back into the home or lead to costly furnace and chimney corrosion. By the mid-1990s, condensing furnaces emerged as a feasible solution. By recovering heat from exhaust gases, the new technology provided a significant increase in efficiency, up to 12% higher than the conventional furnaces on the market at the time.

Starting in 1999, Natural Resources Canada worked with industry to identify barriers and activities to advance the market for residential condensing gas furnaces with energy performance levels of 90% or higher. A market transformation strategy was implemented that included measures for research and development, demonstration projects to prove the potential for energy savings, incentive programs and labelling.

Innovations at the Natural Resources Canada's CanmetENERGY labs helped to overcome early technical challenges such as the selection of appropriate materials and manufacturing techniques to ensure the safe operation of condensing furnaces. Natural Resources Canada also worked with Canadian manufacturers to achieve efficiencies over 90% and assisted with the development of energy performance test procedures. Federal, provincial and utility programs provided incentives for the installation of over 300,000 condensing gas furnaces between 2007 and 2012 (for example, through the ecoENERGY Retrofit – Homes program). As the technology became more familiar to homeowners, the home construction industry and trade associations continually improved installer training so that a qualified workforce would be available in the future to respond to expanding consumer demand. Training was supported by ongoing research and building code changes to ensure high energy efficiency levels, safe operation and long-term durability.

As a result of these measures, the market share of condensing gas furnaces increased from 40% to 80% between 1998 and 2008, and the price decreased by 30%, paving the way for regulated minimum energy performance standards. Following the lead of Ontario and British Columbia, Natural Resources Canada implemented federal standards in 2010, eliminating from the market the least efficient products and enabling even greater uptake. Since federal standards were introduced, market transformation continued through programs like ENERGY STAR®, so that today over 85% of residential gas furnaces for sale in Canada are at least 95% efficient.

Minimum energy performance standards for condensing natural gas furnaces will save Canadian homeowners $124 million on their heating bills in 2020.

Residential windows

Technology and market overview

Windows are an integral part of a building envelope, and while they do not consume energy, they are an important element in determining how much energy is needed to comfortably heat and cool a home. Windows in low-rise residential homes can account for up to 35% of heat loss. They can also supplement the heating system by allowing passive solar gain, but this can increase air-conditioning loads in the summer and affect occupant comfort.

In Canada, the amount of window glass installed in homes and buildings has been increasing steadily over the past 25 years. Statistics show that the glass-to-floor ratio has increased from an average 9% in 1990 to nearly 15% by 2015. Occupants like the natural light and openness created by increased glazing area, but it can come at an energy cost. The need for affordable, high-performance windows has never been so important.

The performance of residential windows has improved over the past 30 years. The increasing use of sealed insulating glass units with two or three panes of glass, low emissivity (low-e) coatings on the glass and inert gas fills has increased the performance by 30% to 40%. The use of non-metal framing materials and improved weather stripping and locking mechanisms has also helped to lower the average U-factor and increase Energy Rating values.

There are several technologies under development that could increase performance by another 50% to 60% or more. They include adding a vacuum and/or aerogel filling to the insulating glass unit, new generation low-e coatings, smart technology that dynamically controls the amount of light and passive solar energy a window transmits, smart blind mechanisms, and the advent of strong light-weight non-metal materials such as carbon fibre. These technologies still require significant research and development efforts before they can become mainstream.

How is energy performance in residential windows measured?

The energy performance of a residential window can be expressed as follows:

- U-factor (or U-value) – a measure of heat transfer from warm to cold areas (in $W/m^2{\cdot}K$, i.e. watts per square metre degree Kelvin).
- solar heat gain coefficient – a measure of passive solar heat gain.
- air leakage – a measure of air transfer through gaps in the window seals or frames (in $L/s{\cdot}m^2$, i.e. litres per second per square metre).
- Energy Rating (ER) – a formula that balances U-factor and air leakage with passive solar heat gain to give an overall indicator of thermal performance.

The main performance metrics used in Canada are U-factor and ER.

Since 2003, ENERGY STAR for residential windows and doors in Canada has pulled the market toward overall better performance. There have been four iterations of the technical specifications since the program's inception, and the criteria are now about 25% more efficient than when the program began. ENERGY STAR has also been greatly helped by incentives and rebates offered for ENERGY STAR certified windows by utilities and the former federal ecoENERGY retrofit program.

In 2009, Ontario became the first province to regulate the energy performance of windows by adopting the minimum ENERGY STAR criteria in effect at that time. British Columbia followed with their own regulation using comparable criteria. The 2010 version of the *National Building Code of Canada* adopted levels from the 2005 ENERGY STAR criteria, which have found their way, in whole or in part, into many provincial building codes. For the window performance levels in current codes, regulations and ENERGY STAR specifications, see Figure 1.

Figure 1. Residential window performance levels in Canada[3]

U-FACTOR W/m² C	CODES AND STANDARDS (zones correspond to number of heating degree days)	ENERGY STAR levels
2.0	British Columbia and Ontario regulations	None
1.8	National Building Code, Zones 4 and 5	None
1.6	National Building Code, Zones 6 and 7A	Zone 1
1.4	National Building Code, Zones 7B and 8	Zone 2
1.2	None	Zone 3
1.0	None	ENERGY STAR Most Efficient

There are approximately 15 large national manufacturers supplying residential windows and doors in Canada, with an estimated 1,400 small to medium-sized manufacturers supplying regional or local markets. There are also distributors that broker the supply channels between manufacturers and buying groups for the numerous small dealers.

The residential window market size is estimated at 12 million square metres of factory-built window products shipped annually, divided 45/55 between the new construction and retrofit markets. The total annual sales are estimated at about $3.1 billion.[4]

Aspirational goals

Governments' short-, medium- and long-term aspirational goals to 2030 for this equipment area can be found in Figure 2. The aspirational goals cover residential windows and sliding glass doors that are factory-built/glazed and used in new construction and existing home retrofits. Unit skylights and hinged doors systems require further discussion to define appropriate performance levels. The goals also include research and development targets to support the development of next-generation technologies.

3 The proportion of Canadian shipments by performance level is unknown. A national market study is underway to provide this information.

4 Statistics based on 2013 Fenestration Canada market study.

Figure 2. Aspirational goals to 2030 for residential windows in Canada

Short term: By 2020, residential windows for sale in Canada meet an average U-factor of 1.6 (or an ER of 25).

Medium term: By 2025,

- All residential windows for sale in Canada meet a U-factor of 1.2 (or an ER of 34).
- Residential windows with a U-factor of 0.8 can be manufactured and installed cost-effectively.[5]

Long term: By 2030, all residential windows for sale in Canada meet a U-factor of 0.8 (or an ER of 40).[6]

Performance levels for windows have traditionally varied by climate zones. However, only one value was chosen for each aspirational goal since higher performance values reduce the range of efficiency levels possible for different climate zones.

Key market barriers

The following have been identified as the barriers to the market adoption of residential windows that perform at levels required to achieve the aspirational goals.

Barriers to meeting the short-term aspirational goal: Windows with a U-factor of 1.6

The short-term aspirational goal is a modest change from existing codes and standards in Canada and represents an achievable incremental increase in efficiency in the short term without a major change in technology. No major barriers to market adoption were identified; however, stakeholders did indicate the need for consistent labelling and certification provisions to identify and confirm window performance.

Barriers to meeting the medium-term aspirational goal: Windows with a U-factor of 1.2

The medium-term aspirational goal would move window construction to a "triple-glaze" technology or equivalent. The key barriers are:

- **Accessibility and Awareness**: Triple-glazed windows tend to be heavier because they contain more glass. This can make installation more difficult and create challenges when integrating them into higher-performing wall systems. In some limited applications, windows at this performance level cannot be installed. If the installation is not done correctly it could create issues such as drafts and water leakage, undermining performance and creating a negative image of the technology with consumers.

- **Affordability**: Windows at this performance level will have higher upfront costs, but they are often recouped within a reasonable time period. These upfront costs can, however, deter the uptake of the higher-performing product in those markets where the purchaser may not be the end user – like in new home construction.

[5] Cost equivalent to a 5% premium over a window with a U-factor of 1.2. This is the estimated cost at which a window with a U-factor 0.8 will become cost-effective versus a window with a U-factor of 1.2. Costs are based on manufacturer and industry estimates collected through Natural Resources Canada's Local Energy Efficiency Partnership Initiative and CanmetENERGY's research programs.

[6] The ER is an approximation.

Barriers to meeting the long-term aspirational goal: Windows with a U-factor of 0.8

The long-term aspirational goal would move window construction beyond triple-glaze technology to a more advanced technology. The key barriers are:

- **Availability and Accessibility**: There is a very limited number of window models available in Canada that can meet this performance level. Having windows at this performance level more broadly accessible would require investments to make them more easily manufactured, affordable and lighter and to develop standardized testing procedures that can measure the performance of new technologies emerging on the market.

- **Awareness**: Market players in Canada have little knowledge that windows at this performance level are available, which means there is little demand and promotion.

- **Affordability**: High upfront manufacturing capital and investment impact the affordability for consumers. A window at this performance level costs significantly more than a standard window. High costs could make less efficient alternatives more attractive (i.e. site-built or refurbished windows).

- **Acceptance**: At this performance level, there may be less selection overall or elimination of certain window styles (e.g. double hung windows or slider windows), which may impact consumer acceptance or usability in retrofit situations. In addition, depending on the low-e coatings used, lower U-factors may create “darker” windows because their construction may reduce or change the quality of visible light that passes through the glass. Durability may also be impacted for these advanced products, which may affect the product life span. As homes become tighter, windows can create comfort issues from overheating, if they are not designed with cooling needs in mind.

Market transformation scorecard – residential windows

Technology	Availability Does the technology exist?	Accessibility Does the market have access to the technology?	Awareness Does the market know about the technology?	Affordability Is the technology affordable?	Acceptance Is the form, fit, and function of the technology acceptable?
Window U-factor 1.6	🟢	🟢	🟢	🟢	🟢
Window U-factor 1.2	🟢	🟢	🟡	🟡	🟢
Window U-factor 0.8	🟡	🟡	🔴	🔴	🟡

🟢 Yes 🔴 No 🟡 to some extent

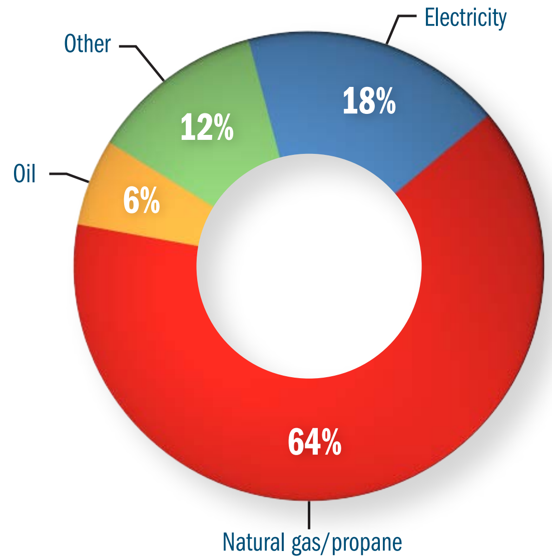
Space heating

Technology and market overview

Living in Canada's cold climate requires large amounts of energy to heat our homes and buildings to maintain comfort. Space heating is therefore the largest source of energy use in the building sector, accounting for 64% and 56%[7] of the total energy consumed in homes and commercial buildings, respectively. Energy consumption for space heating is tied to how efficiently the equipment uses fuel, the energy performance of the building envelope, and other factors like ventilation, climate and occupant behaviour.

In Canada, most heating systems use one of three primary sources of energy: oil, natural gas or electricity. Biomass such as wood or wood pellets is also used in rural Canada and in the North. These energy sources tend to be distributed regionally depending on accessibility and cost; for example, oil is predominantly used in parts of Atlantic Canada, electricity is predominant in Quebec and Manitoba, and natural gas is the main energy source for heating in Ontario, Saskatchewan, Alberta and British Columbia (Figure 3).

Figure 3. Share of energy consumed for space heating in Canada.



How is energy performance in space heating measured?

The energy performance of space heating equipment is expressed as follows:

Gas- and oil-fired equipment

- annual fuel utilization efficiency (AFUE) – a measure of the percentage of fuel that is converted into heating energy and therefore maximum performance is 100%.

Heat pumps

- heating season performance factor (HSPF) or heating coefficient of performance (COP) – a ratio of the useful heat the system is able to pump for each unit of energy, at a specific temperature or climate region.
- seasonal coefficient of performance (SCOP) – a measure of overall heating efficiency for a season that also measures performance at far lower temperatures and gives greater weight to the coldest weather performance.

In contrast to gas- and oil-fired equipment, heat pumps extract heat present in air, water or earth and transfer it indoors. As the technology uses heat already present in the natural environment, it performs at levels beyond 100% (i.e. one unit of energy to run the heat pump creates more than one unit of heat).

7 Natural Resources Canada, National Energy End-Use Database, 2014.

Over the last 15 years, significant improvements have been made in residential gas space heating technology resulting from previous market transformation efforts and regulated standards. Most equipment sold in Canada operates at above 90% energy performance by using condensing technology, the most efficient technology available for fuel-burning equipment. Oil-fired equipment has not seen the same level of investment in technology and remains stagnant with energy performance levels below condensing levels at roughly 85%. While electrical-resistance-based systems operate at 100% efficiency, homeowners are faced with significant heating energy bills in markets where electricity is expensive.

The commercial space heating market, when compared to the residential market, is dominated by much lower energy performance levels. This results largely from the occupant model used in commercial buildings, which creates a disincentive for building owners to invest in higher efficiency equipment as cost savings would accrue for the occupant (Figure 4).

There is technology present or emerging in the market to take the performance of residential and commercial heating equipment in Canada beyond 100%; for example, electric air-source heat pump technology that can now operate effectively in a wide range of climates, including Canada's colder temperatures. These heat pumps also have the added benefit of providing cooling from the same unit, if designed for that purpose.[8] Ground-source or geothermal heat pumps, which use the ground water, earth or both as the source for heating and cooling, are capable of meeting the heating loads of Canadian winters at performance levels greater than 100%. Emerging heat pump technology is also embracing natural gas as a fuel source, with the potential to see significant increases in the efficiency of natural gas-fired equipment.

As home and building envelopes become tighter with more stringent codes, integrating more than one end-use function into a single piece of equipment may become more attractive. For example, combining space and water heating into one unit or using micro-combined heat and power systems could become suitable alternatives. Wood pellets also have a role to play in supporting rural and northern economies, and in providing a cost effective renewable fuel source alternative to oil or propane.

Figure 4. Share of annual shipments in Canada within each space heating technology, by energy performance

Product	% of market with <90% energy performance	% of market with 90–100% energy performance	% of market with >100% energy performance
Residential gas-fired equipment	2%	98%	0%
Commercial gas-fired equipment	91%	9%	0%
Residential oil-fired equipment	100%	0%	0%
Residential electric equipment	0%	90%	10%

8 If heat pumps with cooling capacity are installed in areas where air conditioning was not typically used in the past, it can increase the total energy consumption.

Since the 1990s, most residential space heating equipment in Canada have been subject to energy performance standards under Canada's *Energy Efficiency Act* and provincial regulations, while the ENERGY STAR program has been promoting high efficiency specifications since 2002. These standards have been updated several times to reflect advances in technology, such as condensing gas equipment. Commercial space heating equipment has only recently been added to federal and provincial regulations. The *National Energy Code of Canada for Buildings* includes minimum energy performance requirements for most commercial space heating equipment in new construction projects. In 2012, the *National Building Code of Canada* also added energy performance requirements for all residential space heating equipment in new construction projects.

There is a small number of national manufacturers supplying residential and commercial space heating equipment. They produce approximately 5% of the total yearly shipments of furnaces and boilers and a significant portion of electric baseboards in Canada. Canadian manufacturing is mainly focused on electric and oil-fired furnaces and electric baseboards. The furnace and boiler market alone is estimated at about 350,000 units shipped annually, divided approximately 40/60 between new construction and retrofit markets. The total annual sales for residential and commercial applications are estimated at about $360 million.

Aspirational goals

Governments' short-, medium- and long-term aspirational goals to 2035 for space heating can be found in Figure 5. The aspirational goals cover commercial and residential technologies that use natural gas and electricity.[9] The goals also include research and development targets to support the development of next-generation technologies.

9 Oil-fired technologies would be subject to the aspirational goals, but more work is required to understand the market barriers. For this reason, oil-fired equipment is not discussed in this report.

Figure 5. Aspirational goals to 2035 for space heating in Canada

Short term: By 2025,

- All fuel-burning technologies for primary space heating for sale in Canada meet an energy performance of at least 90% (condensing technology).
- All air-source heat pumps for sale in Canada meet a SCOP greater than 2.5,[10] at least 30% better performance than today.

Medium term: By 2030,

- A residential natural gas heat pump with a SCOP greater than 1.2 can be manufactured and installed cost-effectively.[11]
- A residential cold climate air-source heat pump with a SCOP greater than 2.75 can be manufactured and installed cost-effectively.[12]
- The deployment of heating systems using renewable technologies and renewable resources is supported.

Long term: By 2035, all space heating technologies for sale in Canada meet an energy performance of more than 100%.

The short-term goals will transition the entire market for gas-fired equipment to condensing technology and electric heat pumps to technology capable of operating efficiently and effectively in cold temperatures. In the medium term, the goals lay out research and development targets to support the commercialization, deployment and performance improvements of gas heat pump technology, and deployment and performance improvements for air-source heat pumps. The medium-term goals are also focused on ensuring that barriers are not inadvertently created for the use of biomass and other renewable technologies in remote and northern applications. The long-term aspirational goal is to transition the entire market to technologies that have a performance greater than 100% in cold climates.

Key market barriers

The following have been identified as key barriers to the market adoption of the space heating technologies needed to achieve the aspirational goals. Products subject to ongoing regulatory development at the federal level are not included.

Barriers to meeting the short-term aspirational goal - Condensing gas technology

The short-term aspirational goal would complete the transition of the market for fuel-burning equipment to condensing technology. The focus here is on commercial gas furnaces,[13] and the key barriers are:

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10 For ASHRAE Region V, when tested according to the CSA Express document (currently in draft form) regarding variable capacity heat pumps.

11 The research and development target is only for residential applications. Given the absence of data on the commercial building sector, it was not possible to produce a target for this report. Cost equivalent to a 25% premium over a high efficiency gas furnace. This is the estimated cost at which a natural gas heat pump with a SCOP greater than 1.2 will become cost-effective versus a condensing gas furnace with an AFUE of 95%. This cost is based on manufacturer and industry estimates collected through Natural Resources Canada's Local Energy Efficiency Partnership Initiative and CanmetENERGY's research programs.

12 The research and development target is only for residential applications. Given the absence of data on the commercial building sector, it was not possible to produce a target for this report. Cost equivalent to a 35% premium over a conventional air-source heat pump. This is the estimated cost at which an air-source heat pump with a SCOP greater than 2.75 will become cost-effective versus a conventional air-source heat pump with a SCOP of 1.35-1.45. This cost is based on manufacturer and industry estimates collected through Natural Resources Canada's Local Energy Efficiency Partnership Initiative and CanmetENERGY's research programs.

13 Current federal regulatory development is considering condensing level standards for commercial and residential gas-fired boilers and increasing the minimum performance levels for condensing residential gas-fired furnaces.

- **Accessibility**: Three small-scale manufacturers currently provide high efficiency commercial gas furnaces products in Canada, with only a small percentage of market share. This limits the extent to which these products are accessible to building owners for different end uses.

- **Awareness**: Small-scale demonstration projects have been carried out by some utilities in Canada to show that the technology works, technical challenges can be overcome (e.g. condensate management) and that the equipment is cost-effective. However, engineering service providers and contractors are still not comfortable with the technology because of complex system design and commissioning requirements and are likely to make more conservative choices in the absence of widespread demonstrated performance.

- **Affordability:** The upfront cost of condensing equipment is significantly higher than less efficient, conventional gas furnaces, although energy savings offset these costs in end-use applications where a significant volume of outdoor air is being heated. The occupant model used in most commercial buildings is a barrier since the capital costs are borne by the building owner but the operating cost savings from more efficient equipment would accrue for the occupant.

Barriers to meeting the short-term aspirational goal – Electric heat pumps

The short-term aspirational goal would transition the market for electric heat pumps to products capable of operating efficiently and effectively in cold temperatures. The focus here is on air-source and ground-source heat pumps, and the key barriers are:

- **Availability**: For air-source heat pumps, there is a growing number of product models available in the market that can operate in cold climates. However, of the 200 models in the North East Energy Efficiency Partnerships' database, only nine models would meet the 2025 cold climate performance goals,[14] and none are of commercial size.

- **Accessibility**: While air-source heat pumps capable of operating in cold climates are available in the market, there is no standardized testing procedure to rate energy performance at low temperature. There are also limited testing facilities in Canada capable of rating performance in cold climate conditions. Ground-source heat pumps, on the other hand, have an established testing procedure.

- **Awareness**: Qualified installers are not available across all of Canada. While the technology may be available in local markets, installers may not be, and the performance of these heat pumps depends on the integrity of the installation.

- **Affordability**: The high upfront cost of air-source heat pumps capable of operating in cold climates is a barrier to wide-scale adoption. In regions of Canada where heating costs are very high, consumers will see favourable paybacks, but the upfront cost is still significant and may be a barrier for those that are sensitive to upfront costs. In regions where heating costs are low or where they are being used instead of electric baseboard systems in new construction, these heat pumps may not be cost-effective. Ground-source heat pumps also suffer from the same challenge of high upfront costs, although mainly in residential applications.

- **Acceptance:** The early models of air-source heat pumps capable of operating in cold climates did not function as advertised, which has created skepticism in the building industry about their reliability and performance. While more accurate performance information is now becoming available, these heat pumps still have challenges providing sufficient heat in the coldest temperatures and require a back-up system.

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[14] Based on manufacturers' test data.

In addition, if homeowners currently using baseboard heating switched entirely to a mini-split heat pump system, it could entail higher maintenance costs and could create comfort issues. In the case of ground-source systems, the installation process typically involves a circuit of underground piping outside the building, which is a barrier to wide-scale adoption.

In addition to the market barriers above, wide-scale installation of air- and ground-source heat pumps in regions that are not typically heated by electricity can put pressure on utility grids in provinces that are near their maximum capacity. This may prevent further deployment in those regions.

Barriers to meeting the long-term aspirational goal – Gas heat pumps

The long-term aspirational goal would complete the transition of the entire space heating market to heat pump technology or integrated systems that can achieve greater than 100% energy performance. The focus here is on gas absorption heat pumps.[15]

Gas absorption heat pumps may offer a significant increase in performance beyond that of existing gas-fired heating systems. However, they face barriers to availability, accessibility, awareness, affordability and acceptance because they are not yet commercialized in Canada. The technology is lacking key market and technical development, including making the case for performance and economic payback, ensuring there are no impediments to its commercialization (e.g. in existing codes and standards), demonstrating that the technology can work in cold climates, developing standardized testing procedures and making the market players aware that the technology exists. It is expected that support for research and development through the medium term would resolve some of these issues.

Market transformation scorecard – space heating

Technology	**Availability** Does the technology exist?	**Accessibility** Does the market have access to the technology?	**Awareness** Does the market know about the technology?	**Affordability** Is the technology affordable?	**Acceptance** Is the form, fit, and function of the technology acceptable?
Condensing commercial gas furnaces	Yes	to some extent	to some extent	to some extent	Yes
Ground-source heat pumps	Yes	Yes	Yes	No	No
Cold climate air-source heat pumps	to some extent	to some extent	to some extent	to some extent	to some extent
Gas absorption heat pumps	No	No	No	No	No

Yes No to some extent

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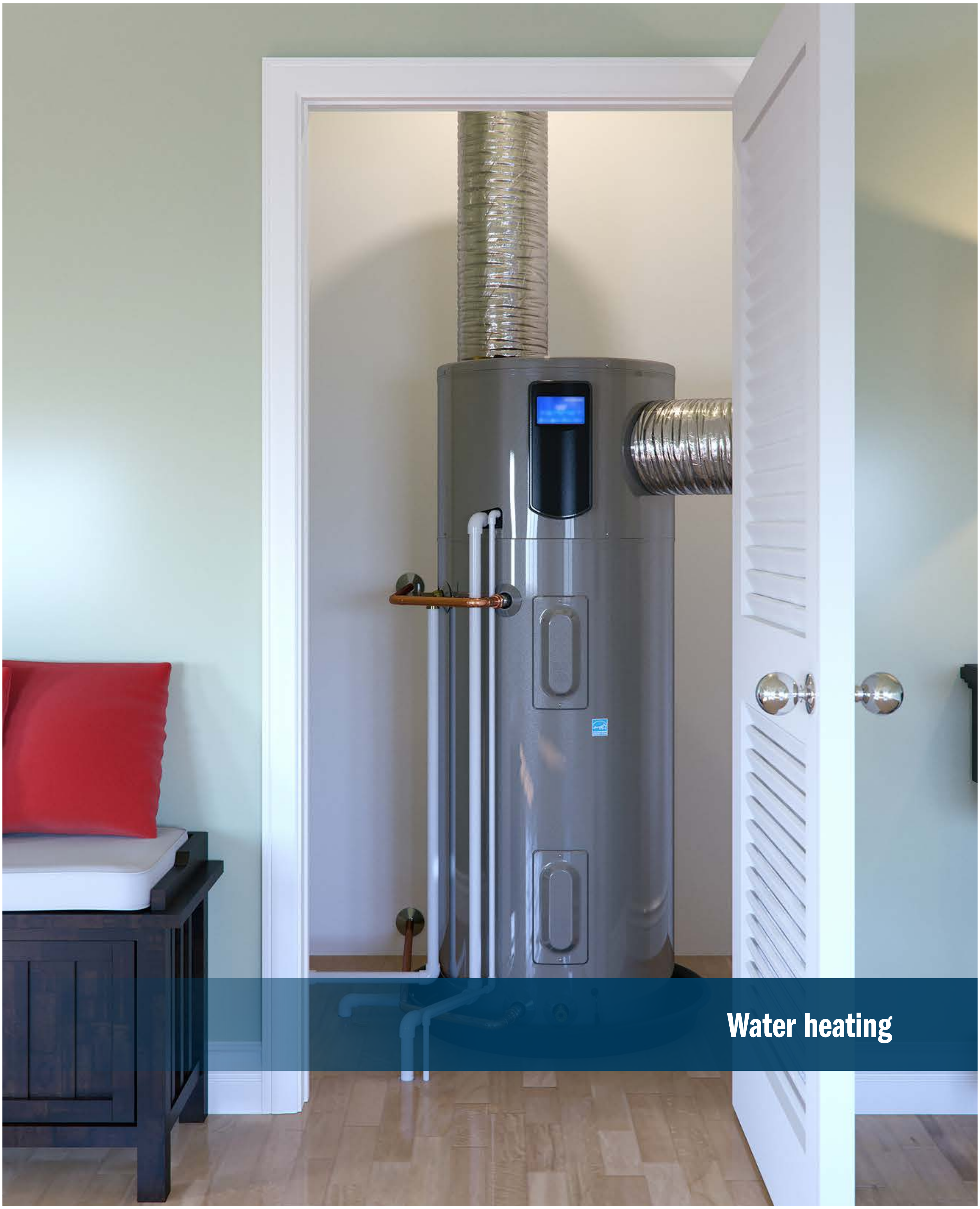
15 Other integrated systems, like combined space and water heating, and micro-combined heat and power, can provide a level of total system performance that meets the aspirational goal. They are not included in this report, as they require further discussion with stakeholders to understand market barriers.



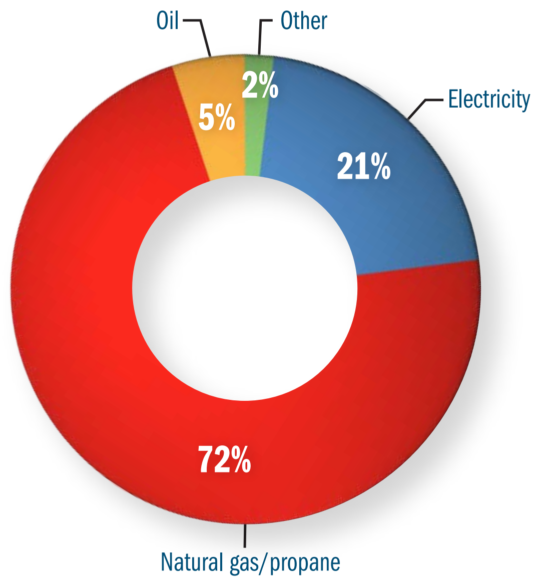
Water heating

Technology and market overview

Hot water for bathing and cleaning is an essential service in our homes and buildings and requires significant amounts of energy. Water heating can be the second-largest source of energy use and accounts for 19% and 8%[16] of the total energy consumed in homes and commercial buildings, respectively. Energy consumption is directly tied to how efficiently water heating equipment uses energy and how often the system needs to run in order to provide water at the right temperature.

In Canada, most hot water systems use three primary sources of energy: oil, natural gas and electricity. Solar domestic hot water systems are also used but to a much lesser extent. Energy sources tend to be distributed regionally depending on accessibility and cost; for example, oil is predominantly used in the North, electricity is predominant in Quebec, Manitoba and Atlantic Canada, and natural gas is the main energy source for water heating in Ontario, Saskatchewan, Alberta and British Columbia (Figure 6).

Figure 6. Share of energy consumed for water heating in Canada.



How is energy performance in water heating measured?

The energy performance of water heating equipment is expressed as follows:

Gas- and oil- fired water heaters

- energy factor (EF) – a measure of the amount of hot water produced per unit of fuel consumed over a typical day. It accounts for standby losses and the operating efficiency of the water heater when it is heating water. The higher the EF, the more efficient the water heater, up to a maximum of 1.

Electric water heaters

- standby loss – an indirect measure of efficiency that indicates the loss of heat from the storage tank in watts, and is correlated to the amount of insulation. Lower standby loss indicates higher efficiency.

Heat pump water heaters

- energy factor (EF) – a measure similar to that for gas- and oil-fired water heaters. The EF is greater than 1 for all heat pumps.

[16] Natural Resources Canada, National Energy End-Use Database, 2014

Two main types of water heaters exist in Canada – the storage tank and the instantaneous water heater. For storage tank water heaters, there has been slow progress in moving to higher efficiencies and performance has remained somewhat stagnant. Currently, gas- and oil-fired storage water heaters operate at around an EF of 0.60-0.68 (equivalent to 70% to 80% in energy performance[17]), while electric storage water heaters have a standby loss of less than 181 watts (equivalent to 100% in energy performance). Much of the gas-fired instantaneous water heater market is at or above EF of 0.8 (equivalent to 90% in energy performance), with the higher efficiency products using condensing technology (Figure 7).

For gas-fired storage water heaters, condensing technology can take the performance of these storage tanks from 70 to 90%. These high efficiency products represent less than 1% of the residential market and roughly 30% of the commercial market. There is a potential for small incremental improvements to the electric storage water heater performance from increased insulation; however, new heat pump technology can take the performance of these storage tanks past 100% (EF greater than 1). Emerging heat pump technology using natural gas as a fuel source may significantly increase performance over current gas-fired equipment. Integrating more than one end-use function (e.g. space and water heating) into a single piece of equipment is also becoming more attractive.

Figure 7. Share of annual shipments in Canada within each water heating technology, by energy performance

Product	% of market with <90% energy performance	% of market with 90–100% energy performance	% of market with >100% energy performance
Residential gas-fired storage water heater	99%	1%	0%
Residential oil-fired storage water heater	100%	0%	0%
Residential and commercial electric storage water heater	0.5%	99%	0.5%
Residential instantaneous water heater	25%	75%	0%
Commercial gas-fired storage water heaters	70%	30%	0%

17 EF accounts for a range of losses, including standby loss and cycling. Energy performance is an approximate measure of the percentage of fuel that is converted into heating energy without losses, and is an attempt to normalize the relative performance across technologies for the limited purpose of understanding the market.

Since 1995, most of the residential water heating energy use in Canada has been subject to energy performance standards under Canada's *Energy Efficiency Act* while the ENERGY STAR program been promoting high efficiency specifications since 2009. The regulated performance standards for gas and electric storage water heaters have been updated twice in the intervening years. Provincial regulations, where they exist, have generally been aligned with federal standards. Since 2012, the *National Building Code of Canada* and the *National Energy Code of Canada for Buildings* have included minimum energy performance requirements for all water heating equipment. Commercial equipment is only now starting to be added to federal and provincial regulations.

There is one national manufacturer supplying residential and commercial water heating storage tanks in Canada. The remaining water heaters are imported mainly from U.S. manufacturers. Instantaneous water heaters are predominantly manufactured by companies based in Asia. The water heating market size is estimated at one million units annually, divided 20/80 between new construction and retrofit markets. The total annual sales for both residential and commercial are estimate at about $350 million.

Aspirational goals

Governments' short-, medium- and long-term aspirational goals to 2035 for water heating can be found in Figure 8. The aspirational goals cover commercial and residential water heating technologies that use natural gas and electricity.[18] The goals also include research and development targets to support the development of next-generation technologies.

Figure 8. Aspirational goals to 2035 for water heating in Canada

Short term: By 2025, all fuel-burning water heating technologies for sale in Canada meet an energy performance of at least 90% (condensing technology).

Medium term: By 2030,

- All electric water heaters for sale in Canada meet an energy performance of more than 100% (EF greater than 1).
- A residential gas heat pump with an EF greater than 1.4 can be manufactured and installed cost-effectively.[19]

Long term: By 2035, all water heating technologies for sale in Canada meet an energy performance greater than 100% (EF greater than 1).

The short term goals will transition the entire market for gas-fired equipment to condensing technology. In the medium term, electric water heaters would transition to heat pump technology. The medium-term goals also lay out research and development targets to support both the commercialization, deployment and performance improvements of gas heat pump technology. The long-term aspirational goal is to transition the entire market to technologies that have an energy performance greater than 100%. While not directly addressed, it is also expected that the performance and cost of electric heat pumps will improve between now and 2035.

18 Oil-fired technologies would be subject to the aspirational goals, but more work is required to understand the market barriers. For this reason, oil-fired equipment is not discussed in this report.

19 The research and development target is only for residential applications. Given the absence of data on the commercial building sector, it was not possible to produce a target for this report. Cost equivalent to a 30% premium over a condensing gas-fired storage water heater. This is the estimated cost at which a gas heat pump with an EF greater than 1.4 will become cost-effective versus a condensing tank with an EF of 0.82. This cost is based on manufacturer and industry estimates collected through Natural Resources Canada's Local Energy Efficiency Partnership Initiative and CanmetENERGY's research programs.

Key market barriers

The following have been identified as key barriers to market adoption of water heating technologies needed to achieve the aspirational goals. Products subject to ongoing regulatory development at the federal level are not included.

Overarching challenge

Reducing the upfront cost of a water heater is a critical issue because replacing a water heater is a reactive and often urgent decision for consumers (e.g. when the existing water heater breaks). For this reason, high upfront costs are one of the biggest barriers to adoption of more efficient products, even when the consumer benefits from a favourable payback in energy savings over the life of the product.

Barriers to meeting the short-term aspirational goal – Condensing gas technology

The short-term aspirational goal would complete the transition of the market for fuel-burning equipment to condensing technology. The focus here is on residential gas-fired storage water heaters,[20] and the key barriers are:

- **Accessibility**: Storage tanks using condensing technology are not widely accessible in all sizes of residential water heaters sold today, which makes them less attractive to wholesalers and contractors that want to have product lines marketable to all end-use applications. This translates into a limited number of product models being available in the market.

- **Awareness**: Mechanical contractors and consulting engineers are not very familiar with this technology. When contractors and engineers are uncomfortable with a new technology due to lack of "know-how" or ability to install, they are unlikely to recommend the product.

- **Affordability:** The high upfront cost, coupled with the low cost of natural gas, makes the economic payback longer than the life expectancy of the product. The demand for this product is also very low, and consequently the volume of current sales is not sufficient to bring costs down. Even with a positive payback, the purchaser will have little incentive to buy the more efficient equipment if they are not directly paying the cost of heating the water (e.g. condo owner versus renter; provinces with water heater rental markets).

Barriers to meeting the medium-term aspirational goal: Electric heat pumps

The medium-term aspirational goals would transition electric water heaters to heat pump technology. The key barriers are:

- **Accessibility**: There is no standard approach for calculating the energy performance of heat pump water heaters in Canadian climate conditions while ensuring it also meets national health requirements for minimum water temperature. It is therefore difficult to predict energy savings over the life of the product. There is also very limited access to these products in the market.

- **Awareness**: Mechanical contractors, consulting engineers and specifiers are not very familiar with this technology. When contractors and engineers are uncomfortable with a new technology due to lack of "know-how," they are unlikely to recommend the product. There are also no commonly accepted installation practices and guidelines for retrofit applications.

- **Affordability**: The high upfront cost currently means that consumers may not see a positive payback. The demand for this product is very low, and consequently the volume of current sales is not sufficient to bring

[20] Current federal regulatory development is considering condensing technology level standards for commercial water heaters and instantaneous water heaters.

costs down. Even with a positive payback, the purchaser will have no incentive to buy the more efficient equipment if they are not directly paying the cost of heating the water (e.g. condo owner versus renter, provinces with water heater rental markets).

- **Acceptance:** Electric heat pumps have a number of outstanding technical issues that need to be resolved. For example, water heaters are located in a heated space such as the basement, which means that the heat pump is using heated air around the storage tank. This requires the home's heating system to work longer to replace that heat. Avoiding this situation can require additional ducting, which makes retrofit installations a challenge. If heat is taken from the outdoor air, the heat exchanger can freeze up, reducing performance. In addition, maintenance requirements and durability, such as filter replacements and refrigerant recharging, are not well known and understood. There may also be technical barriers to meeting higher loads in commercial applications. Finally, heat pumps installed in small spaces may create noise, and have size constraints.

Barriers to meeting the long-term aspirational goal: Gas heat pumps

The long-term aspirational goals would transition the entire water heating market to heat pump technology or integrated heating systems that can achieve greater than 100% energy performance. The focus here is on gas absorption heat pump technology.[21]

Gas absorption heat pumps may offer a significant increase in energy performance beyond existing condensing gas systems. However, they face barriers to availability, accessibility, awareness, affordability and acceptance because they are not yet commercialized in Canada. The technology is lacking key market and technical development, including making the case for performance and economic payback, ensuring there are no impediments to its commercialization (e.g. in existing codes and standards), demonstrating the technology can work in cold climates, developing standardized testing procedures and making the market players aware the technology exists. It is expected that support for research and development through the medium term will resolve some of these issues.

Market transformation scorecard – water heating

Technology	**Availability** Does the technology exist?	**Accessibility** Does the market have access to the technology?	**Awareness** Does the market know about the technology?	**Affordability** Is the technology affordable?	**Acceptance** Is the form, fit, and function of the technology acceptable?
Condensing storage tanks	Yes	to some extent	to some extent	No	Yes
Electric heat pump water heaters	Yes	to some extent	to some extent	No	No
Gas absorption heat pump water heaters	No	No	No	No	No

Yes No to some extent

[21] Other integrated systems, like combined space and water heating, and solar-powered water heating can provide total system performance that meets the aspirational goal but require further discussion with industry to understand market barriers.

OVERCOMING MARKET BARRIERS

There are many measures that governments can engage in or use to help overcome the market barriers identified in this report. These measures cover the full spectrum of activities from research and development to regulations, and many require partnerships and collaboration with other market players. Governments will work with stakeholders to select and implement the most appropriate measures for each equipment area and jurisdiction as road maps are developed to reach the aspirational goals.

Research and development

- Use research and development targets (cost and performance levels) to inform funding priorities at the federal level. Research and development can:
    - Support improvements in residential window design, including improved low-e coatings, "thin triples," smart windows, aerogel fill, vacuum glazing, photovoltaics, better designs, and improved manufacturing processes to lower costs.
    - Overcome technical challenges and further improve performance of electric heat pump water heaters, including CO_2-based refrigerant systems.
    - Improve the performance and cost of electric heat pumps capable of operating in cold temperatures.
    - Support commercialization of gas heat pumps, including improvements in cost and performance in cold temperatures.
- Explore opportunities to collaborate with the United States where their research and development priorities for residential windows, space heating and water heating align with Canadian interests.
- Create and/or update standards to allow for testing and rating indices for emerging window technologies and heat pump technologies in Canadian conditions.

Capacity building

- Undertake field projects with partners, e.g. utilities, for:
    - Commercial condensing gas furnaces, to better understand economics, installation and performance.
    - Electric heat pump water heaters, to address installation challenges, and better understand performance and long-term maintenance costs.
    - Gas heat pumps, to better understand economics and performance.
- Explore opportunities for partnerships with property management companies, homebuilders, renovators and others who would agree to install equipment in their buildings to demonstrate proof of concept, and long-term performance.
- Develop and disseminate case studies and best practice guides to inform equipment choices among contractors, engineering firms and builders.
- Build capacity in training, design, installation and commissioning through trades, universities, colleges, and other programs for quality installation and maintenance (e.g. certification program, new curriculums).
- Coordinate with the National Research Council to determine how installation issues can be addressed in future building codes.

Market activities

- For space and water heating equipment, conduct an assessment to determine the optimal technologies by region, given differing fuel mixes, greenhouse gas emission grid intensities, heating loads and energy prices. This assessment can identify regional opportunities for programs to accelerate market uptake of specific technologies.
- Consider higher ENERGY STAR performance levels that are aligned with the aspirational goals, to accelerate deployment of residential window models with higher performance levels, cold climate air-source heat pumps, condensing commercial gas furnaces, condensing gas-fired storage water heaters, electric heat pump water heaters, and gas heat pumps.
- Encourage demand-side incentives through provincial utility programs and provincial incentives aligned with aspirational goals.
- Encourage supply-side incentives to build Canadian capacity for manufacturing emerging technologies (e.g. British Columbia incentive for high-performance windows).
- Identify partnerships with other jurisdictions to scale-up market uptake of the more efficient equipment, including northern U.S. states, retailers, distributors and manufacturers.
- Consider federal regulations to:
    - Introduce reporting, certification and labelling requirements for residential windows.
    - Implement standards for commercial gas furnaces at a condensing level technology by 2025.
    - Implement standards for residential gas-fired storage water heaters to the condensing level by 2025.
    - Implement testing standards and reporting of air-source heat pumps in cold climate conditions by 2025.
- Coordinate federal and provincial regulatory activities to ensure harmonized minimum energy performance requirements across Canada.

NEXT STEPS

Market transformation is an important component of the *Pan-Canadian Framework on Clean Growth and Climate Change* and Canada's long-term transition to a low-carbon economy. It provides a pathway for moving the market toward the next generation of high-efficiency equipment, enabling significant energy use and greenhouse gas emissions reductions.

Market transformation can only effectively happen when there are clear, long-term goals and market players are working toward achieving common outcomes. The aspirational goals presented in this report provide those directional goals, representing a common view among Governments for ambitious, yet achievable, performance levels given the technology on the market today.

Moving forward, Governments will engage stakeholders on developing concrete road maps to meet the aspirational goals outlined in this report. Discussions will confirm the market barriers in this report, coordinate measures to overcome them, focus research and development activities, and develop indicators to track progress.

- Fall 2017: Launch stakeholder-government technical groups to develop road maps.
- Fall 2018: Complete equipment road maps to identify measures and indicators.
- 2019: Begin implementation activities in support of the short-, medium- and long-term goals.
- 2021–2022: Complete short-term goals through amendments to federal and/or provincial energy efficiency regulations.

Federal, provincial and territorial governments will report back to ministers next year on progress.

Summary of the aspirational goals

WINDOWS

Short term (2020): Residential windows for sale in Canada meet an average U-factor of 1.6 (or ER of 25).

Medium term (2025):

- All residential windows for sale in Canada meet a U-factor of 1.2 (or ER of 34).
- Residential windows with a U-factor of 0.8 can be manufactured and installed cost-effectively.

Long term (2030): All residential windows for sale in Canada meet a U-factor of 0.8 (or ER of 40).

SPACE HEATING

Short term (2025):

- All fuel-burning technologies for primary space heating for sale in Canada meet an energy performance of at least 90%.
- All air-source heat pumps for sale in Canada meet a SCOP greater than 2.5.

Medium term (2030):

- A residential natural gas heat pump with a SCOP greater than 1.2 can be manufactured and installed cost-effectively.
- A residential cold climate air-source heat pump with a SCOP greater than 2.75 can be manufactured and installed cost-effectively.
- The deployment of heating systems using renewable technologies and renewable resources is supported.

Long term: All space heating technologies for sale in Canada meet an energy performance of more than 100%.

WATER HEATING

Short term (2025): All fuel-burning water heating technologies for sale in Canada meet an energy performance of at least 90%.

Medium term (2030):

- All electric water heaters for sale in Canada meet an energy performance of more than 100%.
- A residential natural gas heat pump with an EF greater than 1.4 can be manufactured and installed cost-effectively.

Long term (2035): All water heating technologies for sale in Canada meet an energy performance greater than 100%.