Paving the Road to 2030 and Beyond: Market transformation road map for energy efficient equipment in the building sector

Supporting the transition to a low-carbon economy

Energy and Mines Ministers' Conference

Iqaluit, Nunavut

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EXECUTIVE SUMMARY

The *Pan-Canadian Framework on Clean Growth and Climate Change* (PCF) outlines the commitments of the federal, provincial and territorial governments (Governments) to reduce greenhouse gas (GHG) emissions and promote clean, low-carbon economic growth for Canadians.

To support the commitments of the PCF, the Governments outlined a series of aspirational goals for energy performance of key equipment technologies and market transformation needs in a report released at the Energy and Mines Minister's Conference in August 2017 entitled *Market transformation strategies for energy-using equipment in the building sector.*[1] Governments are focusing their collaborative efforts on market transformation for residential windows, space heating and water heating since they offer significant opportunities to reduce energy use (over 35%) when next generation technologies are installed.

Over the last year, a series of stakeholder consultations were held to identify the barriers to market adoption of higher efficiency technologies needed to achieve the aspirational goals, and help develop this market transformation road map for windows, space heating, and water heating. The objective of this road map is to outline the key initiatives that provide solutions to the market barriers identified, as well as their respective timelines, roles and responsibilities for each stakeholder group, and indicators to track success over time. This road map serves as a basis for collaborative government-stakeholder activities between now and 2025. With its successful implementation, this plan will pave the way to broad market adoption of next-generation, clean technologies needed for a low carbon building sector.

Figure ES-1 provides an overview of the road map, which builds off the 2017 market transformation strategies report. It includes the following:

- **Initiatives to address market barriers**: The road map summarizes high priority initiatives to address key technical and market barriers for residential window, space heating, and water heating technologies given that each equipment technology has unique challenges in their respective market. Initiatives are grouped in the following seven steps: product development, lab and field testing, large-scale demonstrations, information and awareness, training, incentives, and codes and standards. The initiatives are also sequenced over time and mapped against the barrier they help overcome.

- **Roles and responsibilities:** While Governments play a lead role in many of the initiatives because they have access to the tools, levers and resources required, lead and supporting roles are identified for other players in the market place such as utilities, manufacturers, builders, contractors, research organizations, industry organizations, and codes and standards development organizations. Coordination and support from all players are essential to ensure sustained momentum in the market place.

[1] Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf

- **Tracking progress:** As Governments and stakeholders implement the road map initiatives, they must track the progress of each initiative in overcoming the technical and market barriers. These indicators could help Governments and stakeholders understand whether the market is changing and adapt the initiatives as necessary to align with market needs.

As a next step, Governments will launch small implementation teams in fall 2018 to flesh out the road map initiatives into more detailed work plans and engage the stakeholders that need to be part of each initiative's key activities. This road map will be formally updated in five years, based on input from the implementation teams.

ES-1 Overview of the Road Map

ASPIRATIONAL GOALS FOR ENERGY PERFORMANCE IN WINDOWS, SPACE HEATING AND WATER HEATING

Goals support the objectives of reducing greenhouse gas emissions and promoting the adoption of clean technologies by 2030 and beyond

IDENTIFYING MARKET BARRIERS

Market transformation scorecards developed for each technology based on the five A's

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

ADDRESSING MARKET BARRIERS

Initiatives are developed, prioritized and sequenced by Governments and stakeholders and organized in the following seven steps

Product Development R&D	**Lab and Field Testing R&D**	**Demonstrations**	**Information and Awareness**	**Training**	**Incentives**	**Codes and Standards**
Designing products to improve their performance, lower costs, and make them easier to install and control	Simulating operations of a product in a lab or in real-life conditions to assess how well it works	Demonstrating product performance and solutions to installation challenges	Educating the marketplace on how new technologies work and their benefits, to enable wider adoption	Ensuring a trained and certified workforce to install and maintain new products	Ensuring that financial and non-financial measures are in place to make high performance products more affordable	Establishing high-performance specifications to drive innovation and ensuring building codes and standards are harmonized across Canada
Sample initiatives						
Research to lower costs and improve durability of high efficiency windows	*Conduct field and lab testing for gas heat pumps in Canadian climates*	*Conduct demonstrations of cold climate heat pumps to support nation-wide marketing*	*Support consistent labelling for high efficiency windows*	*Improve building designer and contractor awareness for advanced water heating systems*	*Develop and implement incentives and other financial mechanisms for high efficiency windows*	*Support building code and insurance practice harmonization to reduce installation barriers for new water heating technologies*

ROLES AND RESPONSIBILITIES

Roles and responsibilities for Governments and stakeholders are defined for each high priority initiative

TRACKING PROGRESS

Indicators for tracking progress against the five A's are defined

OUTCOMES

- Sustained and ongoing reductions in greenhouse gas emissions
- Canadians have access to high-performance technologies that are cost-effective and work in Canada's climate
- R&D investments support emerging technologies
- Canada has strong contractor expertise and a stronger manufacturer base to supply, install and maintain new 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
- Canadians use clean energy efficiently

1. INTRODUCTION

1.1. Background

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

Residential and commercial buildings account for 17% of total GHG emissions in Canada. Achieving the PCF's emission reduction objective requires a comprehensive plan to lower emissions from the built environment.

Federal, provincial and territorial governments outlined a series of aspirational goals for energy performance of key equipment technologies and market transformation needs in a report released at the Energy and Mines Ministers' Conference in August 2017 entitled *Market transformation strategies for energy-using equipment in the building sector*.[2] Governments are focusing their collaborative efforts on market transformation for residential windows, space heating and water heating since significant improvements in their energy performance is required to achieve commitments set out in the PCF and the longer-term transition to a low-carbon economy.[3]

- **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 GHG emissions could be 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 GHG emissions could be 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 GHG emissions could be lowered by more than 3 megatonnes.

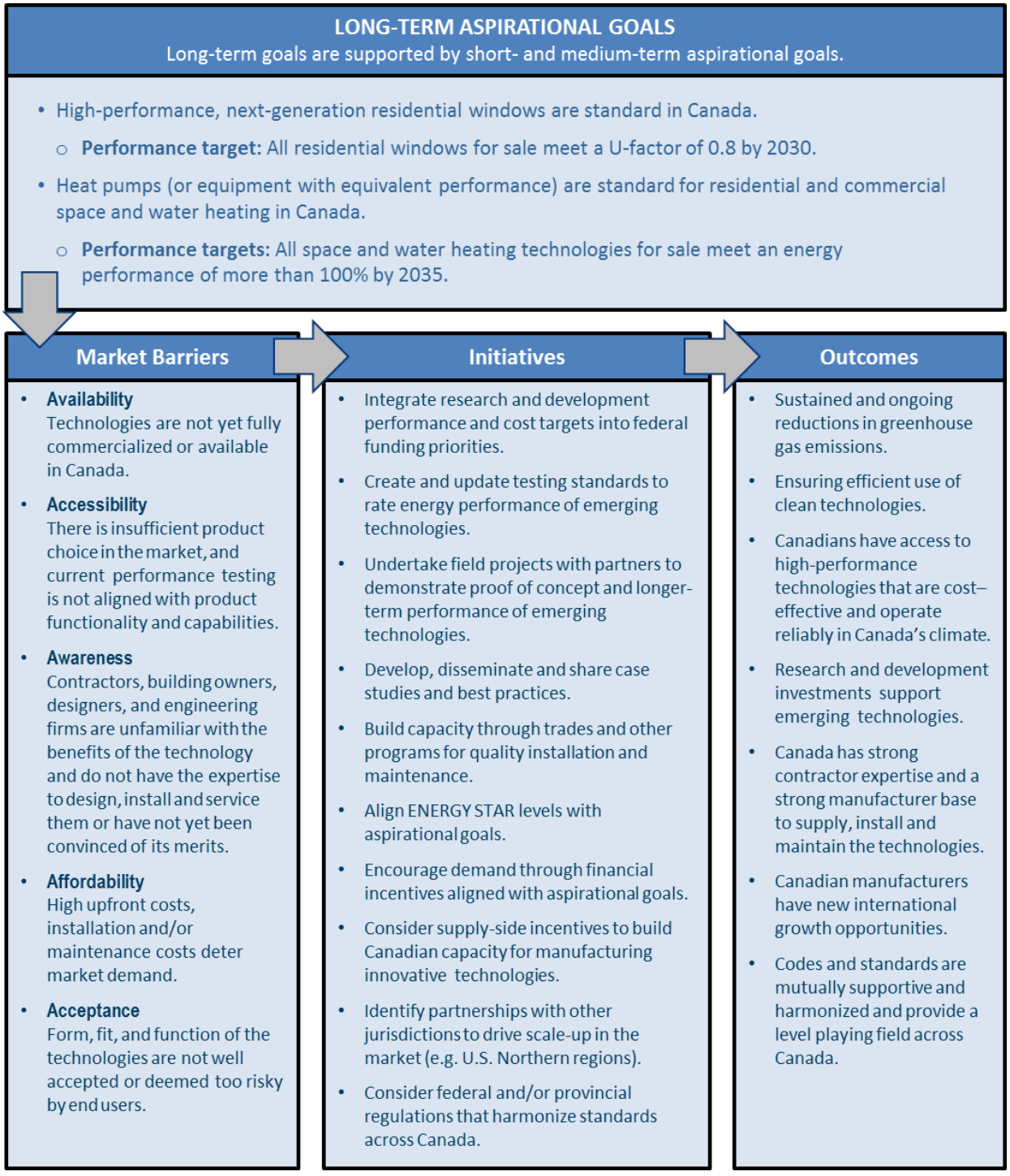
An overview of Governments' market transformation strategy is shown in Figure 1-1 below.

To support further discussions and program planning, Natural Resources Canada (NRCan) engaged Navigant Consulting, Inc. (Navigant) to help develop a market transformation road map for windows, space heating, and water heating. This road map outlines the key road map elements, including priority research and development (R&D) and market deployment initiatives required to overcome market barriers, as well as their respective timelines, roles and indicators to track success. The road map serves as a basis for collaborative government-stakeholder initiatives and activities between now and 2025.

[2] Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf
[3] Ibid

This complete, detailed road map is intended for a technical audience (e.g., researchers, manufacturers, etc.), with the Executive Summary and other supporting materials designed for a broader audience.

Figure 1-1 Market Transformation Strategy Overview



1.2. Objective of road map

Transforming markets to achieve energy efficiency and climate goals requires a series of strategic interventions to induce lasting changes in their structure and function, or in the behaviour of market participants. Governments play a key role in market transformation because they have access to tools, levers and resources that could address barriers which the market cannot overcome on its own; for example, financing R&D, implementing certification schemes or developing regulations. Initiatives typically focus on making a technology available, accessible, and affordable, while ensuring market players are aware it exists and accept its form, fit and function.

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?

Through stakeholder consultations held in spring 2017, NRCan identified numerous market barriers to overcome in windows, space heating and water heating markets. The objective of this road map is to outline the key initiatives that provide solutions to these barriers, and pave the way to broader market adoption of higher efficiency technologies. The key desired outcomes are as follows:

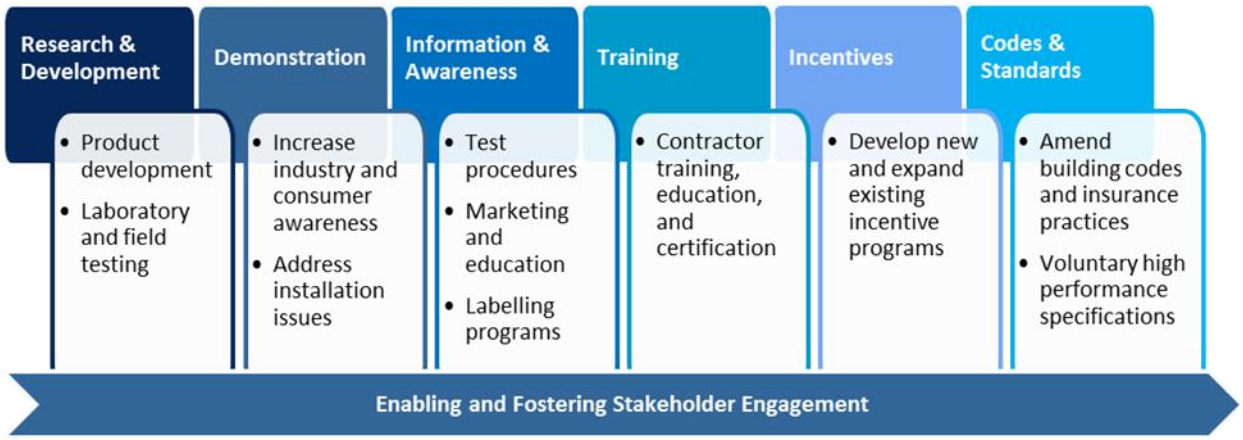
- Identify R&D as well as market deployment initiatives that are essential to overcome barriers to the adoption of highly efficient window, space heating, and water heating technologies between now and 2025;
- Clarify roles and responsibilities, and areas of collaboration in the implementation of high priority R&D and market deployment initiatives; and
- Outline the steps necessary to ensure the successful implementation of the road map, including indicators to track progress.

R&D includes laboratory research, product development, laboratory and field testing, component design, and other research activities that bring technologies to initial market introduction and early adoption stage.

Deployment includes the development of test standards, education and training programs, consumer marketing, incentive programs, large scale demonstration projects and other activities that encourage wider adoption of technologies.

While each product category has unique challenges and barriers in their respective markets, there are several common steps that emerge across the road map initiatives, summarized in Figure 1-2.

Figure 1-2 Common Steps for Road Map Initiatives



- **R&D**: For many equipment types, additional research is necessary to develop the next generation of technologies, control strategies, and installation techniques for Canadian buildings to improve performance and/or reduce costs. The initiatives described in this road map include benchtop research, product development, and laboratory and field testing to evaluate the performance of advanced equipment and systems.

- **Demonstration**: In many cases, technologies that meet Governments' goals are commercially available, but require greater support to demonstrate performance and savings, and understand installation challenges to achieve greater market presence. The initiatives described in this road map aim to prove technology performance to industry and consumer audiences and address installation issues that contractors and builders might experience**.**

- **Information & Awareness**: Building owners and developers, design engineers, and contractors hesitate to recommend or purchase technology they are uncomfortable with or that may not have a short financial payback period. Furthermore, emerging technologies typically require new or updated test procedures to evaluate and rate product performance. The initiatives described in this road map support greater access to new technologies by providing the industry with knowledge about and confidence in savings and economics through measures like the Local Energy Efficiency Partnerships (LEEP) for builders, test procedure development, labelling programs, and marketing campaigns.

- **Training**: New technologies often involve unfamiliar or additional installation, operations, and maintenance requirements for builders and contractors. The initiatives described in this road map aim to develop training, education, and certification programs to increase contractor familiarity with the design and installation practices for new technologies and provide assurances in quality installation.

- **Incentives**: Higher upfront costs of more efficient technologies can be a deterrent to market adoption. Stakeholders must work together to encourage downstream market demand through a combination of financial and non-financial incentive programs. Many utilities and efficiency organizations operate incentive programs to reduce the incremental cost of high efficiency products and encourage adoption. The initiatives described in this road map could support and expand these utility and efficiency programs across Canada.

- **Codes & Standards**: Even if technologies are commercially available, existing building codes, insurance practices, and other codes and standards could limit the market accessibility for new technologies. In addition, manufacturers have limited incentive to manufacture the highest performing products without a clear market signal. The initiatives described in this road map aim to provide technical information and educational materials on new technologies to expedite updates to applicable codes and standards, and reduce stakeholder uncertainty around compliance. In addition, they aim to create voluntary challenge specifications which can help consumers identify high performance products and support incentive program development by utilities and efficiency organizations.

All initiatives in the road map have been categorized into one of the steps listed above. Certain initiatives fall into multiple steps and have been categorized in the step with which they most-closely align.

2. ROAD MAP APPROACH

This section describes the road map methodology and how it has been applied. The key stages of road map development are outlined in Figure 2-1.

Figure 2-1 Road Map Development Stages

Stage 1. Characterize technologies and markets

The first step in the road map process was to characterize the energy-using technologies and the current markets in Canada. This was largely informed by the 2017 report entitled *Market transformation strategies for energy-using equipment in the building sector*. The purpose of that report was to outline Governments' short, medium and long-term aspirational goals for energy performance of windows, space heating, and water heating, and identify key barriers to market adoption for each product category.

Stage 2. Identify initiatives to overcome barriers

In the second stage of the road map, Governments and Navigant held stakeholder workshops in late 2017 and early 2018 to identify and prioritize initiatives that could overcome the barriers hampering success of achieving the aspirational goals. Five workshops were held, covering windows, space heating, and water heating. For each technology type, one workshop focused on R&D opportunities, while the other workshop focused on deployment opportunities.[4] During these workshops, stakeholders discussed potential initiatives in large group-sessions, and smaller break out sessions.

For the break out sessions, the '5A's framework' was used to facilitate stakeholder discussion to develop a clearer understanding of the market barriers present for each product category, and identify initiatives that would overcome those barriers. At the conclusion of each workshop, stakeholders voted on the potential initiatives to determine which should have the highest priority for implementation.

The results of these workshops were summarized into reports and circulated to stakeholders for further comment. In addition, Navigant conducted multiple one-on-one interviews with stakeholders to capture further insights.

Stage 3. Prioritize initiatives

In the third stage of the road map, Governments and Navigant prioritized the R&D and market deployment initiatives collected from stakeholders. They aggregated similar initiatives, ranked them by participant votes[5] and further prioritized the aggregated initiatives using the metrics defined in Table 2-1 and the weightings in

Table 2-2.

[4] Space heating and water heating were jointly covered in one deployment workshop.

[5] In order to incorporate voting from the stakeholder forum, Navigant assigned an industry-input score (0-5) to each initiative, depending on the relative number of votes received. Each point on the industry-input score corresponded to a boost in final score of 0.05 (applied after scoring of prioritization metrics from table 2-1). For example, an initiative with a prioritization score of 3 and an industry-input score of 4 would receive a final score of 3.2 (i.e., 3+ (0.05)*4 = 3.2).

Table 2-1 Initiative Scoring Metrics – Definitions

Metric	Definition
Effectiveness of overcoming barriers	The projected ability of the initiative to overcome major technical and market barriers, and the ability of the initiative to provide breakthrough vs. incremental impacts.
Fit with goals and timeline	Suitability of initiative (e.g., research stage and needs) to the PCF's mission, goals, and capabilities (including the initiative's expected time to market).
Fit with government mission	Suitability of initiative for federal, provincial, and territorial government participation, considering both their sphere of influence, and other participating stakeholders (e.g., U.S. research efforts).
Feasibility	The projected ability of stakeholders to perform the initiative, including Canadian capacity for research and market uptake, funding, resource, legal, and other restrictions.

Table 2-2 Initiative Scoring Metrics – Scoring Legend

Metric	5	4	3	2	1	Wgt
Effectiveness of overcoming barriers	High	High-Moderate	Moderate	Low-Moderate	Low	**30%**
Fit with goals and timeline	High	High-Moderate	Moderate	Low-Moderate	Low	**30%**
Fit with government mission	High	High-Moderate	Moderate	Low-Moderate	Low	**20%**
Feasibility	High	High-Moderate	Moderate	Low-Moderate	Low	**20%**

Only the highest priority initiatives are included in the road map. A summary of the lower priority initiatives can be found Appendix 7.5.

Stage 4. Prepare road map

The final step was to develop the road map for each technology, which includes a description of the technologies, list of key technical and market challenges, and a list of priority R&D and market deployment initiatives per product category. Prioritized initiatives are explained, and include a list of stakeholder roles, key activities and timelines.

Key stakeholder roles were assigned to each initiative. Initiatives typically require collaboration amongst lead and supporting organizations to define objectives, carry out activities, promote findings and resources, etc. Lead organizations have a primary role in funding, organizing, and performing the various initiative activities. Supporting organizations have a secondary role providing guidance and expertise, reviewing materials, performing some of the activities within the initiative, and promoting the initiative outcomes to their wider audiences. The responsibilities and relationship between lead and supporting organizations will depend on the specific initiative.

The road map also includes a summary of market deployment success factors, and an implementation plan with indicators that stakeholders could use to track success.

The prioritized set of initiatives and road map was reviewed by a series of stakeholders including experts from NRCan, CanmetENERGY, provincial and territorial governments, as well as an Advisory Task Group consisting of utility companies / system operators, codes and standards organizations, and industry organizations.

3. RESIDENTIAL WINDOWS

This section contains a R&D and deployment road map for residential windows. [6]

3.1. Technology description

Windows are a two-way street when it comes to energy. They allow heat to escape but also allow passive solar heat gain. Windows in low-rise residential homes can account for up to 35% of heat loss during the heating season, some of which (about 15%) can be offset through passive solar heat gain. During the cooling season, solar gain can increase air-conditioning costs and adversely affect the comfort of the home occupants.

In Canada, the amount of window glass installed in homes and buildings has increased steadily over the past 25 years. Statistics show that the glass-to-floor area ratio has increased from an average of 9% in 1990 to nearly 15% by 2015.[7] The increase in glass-to-floor area ratio over the past decades is primarily due to the growing preference of home and building occupants for more natural light, and other aesthetic benefits of larger windows. However, an increased glass-to-floor ratio results in higher heat loss in the heating season, and higher solar heat gain in the cooling season.

Energy performance for residential windows is measured through several metrics, which each cover a different product attribute. A summary of the metrics used to measure window performance is contained in Figure 3-1.

Figure 3-1 Window Energy Performance Measurements

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/m2·K, i.e. watts per square metre degree Kelvin).*
- *Solar heat gain coefficient (SHGC) – 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·m2, 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.

[6] This road map focuses on improving the energy efficiency of windows to reduce site energy consumption, and does not evaluate source energy consumption and emissions, which vary by location across Canada.

[7] NRCan. 2017. "Market transformation strategies for energy-using equipment in the building sector." August 2017. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf

Window performance has improved significantly over the last 25 years due to the increased adoption of technologies like sealed insulating glass units with two or more panes of glass, low emissivity (low-e) coatings, inert gas fills between the glazing cavity (e.g. argon or krypton), non-metal and thermally-broken framing materials and improved weather stripping and locking mechanisms.

There are now emerging technologies under development that could increase window performance by at least 50% to 60% relative to current technologies. These technologies still require significant R&D efforts before they can become mainstream, but could be vital in achieving long-term aspirational goals for energy performance. A few examples of these technologies are:

- Vacuum and/or aerogel filling to the insulating glass unit;
- Thin triple pane windows, i.e., “thin triples”;
- Improved low-e coatings;
- Smart technology that dynamically controls the amount of light and passive solar energy a window transmits;
- Smart blind mechanisms; and
- Improved light-weight non-metal highly insulating materials (e.g. carbon fibre).

In addition to technologies with higher efficiencies, installation, sizing and integration with wall components are vital for ensuring the overall performance of windows.

Figure 3-2 highlights the Governments' short-, medium-, and long-term aspirational goals for energy performance of residential window technologies, and includes an R&D target that supports the development of next generation technologies.[8] The aspirational goals are currently articulated using U-factor and ER performance metrics. The selection of the appropriate performance metric(s) is a high priority and one of the first initiatives under the road map, as described in the section entitled 'U-factor and ER Approach'.

Figure 3-2 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 (R&D target).*

Long term: *By 2030,*

- *All residential windows for sale in Canada meet a U-factor of 0.8 (or an ER of 44).*[9]

[8] Unit skylights and hinged door systems are not included in these goals as they require further discussion to define appropriate performance levels. Patio doors also require further discussion to determine whether they should remain within the scope of these goals or included with hinged door systems.

[9] An ER of 40 was cited in the August 2017 market transformation strategies report. This number has been updated to an ER of 44 based on the March 2018 study by Posterity Group entitled "U-factor and Energy Rating Equivalence Analysis."

3.2. Key technical and market challenges

Table 3-1 outlines key barriers for window technologies. Barriers have been broken into technical barriers and market barriers, respectively.

Table 3-1 Technical and Market Challenges and Barriers

	Challenge / Barrier	Description
	Product Attributes	Higher efficiency windows may have size, weight, and other attributes that make installation more difficult. In addition, depending on the low-e coating used, lower U-factors with lower SHGC may appear to be darker in colour, an attribute which may not be desirable for consumers. Finally, durability could also be an issue for advanced products.
	Test Procedures and Labelling	Smart and dynamic windows require additional test procedure and performance ratings development, as well as standardized labelling.
	Retrofit Challenges	For existing buildings, there may be challenges with the interoperability of certain high efficiency windows and the associated window frames.
Market	**Product Availability**	There are a limited number of models available in Canada that meet a U-factor of 0.8.
	Training for Contractors	Contractors may have limited experience and knowledge of the design, installation, durability, comfort enhancements and economic payback of high efficiency residential windows. New technologies may carry additional installation, operations, and maintenance requirements for contractors.
	Higher Upfront Cost	High efficiency windows may have higher upfront costs, which could lead to longer paybacks for certain regions; and is a disincentive for homeowners with a limited budget and building owners who do not pay the utility bills.
	Customer Awareness of Technologies	Consumers are not aware of the benefits of high efficiency windows. Consistent labelling and certification provisions are also required to identify and confirm window performance.
	Regulatory Compliance	There is a lack of confidence by industry that a robust compliance system exists across Canada where mandatory requirements are currently in place. A lack of confidence by industry could become a barrier if manufacturers resist making investments to increase window performance because they do not feel there is a level playing field in the market.

Figure 3-3 summarizes the current technology and market status for window technologies in the "5A's framework".

Figure 3-3 5A's for Window Technologies

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

3.3. Road map for residential window technologies

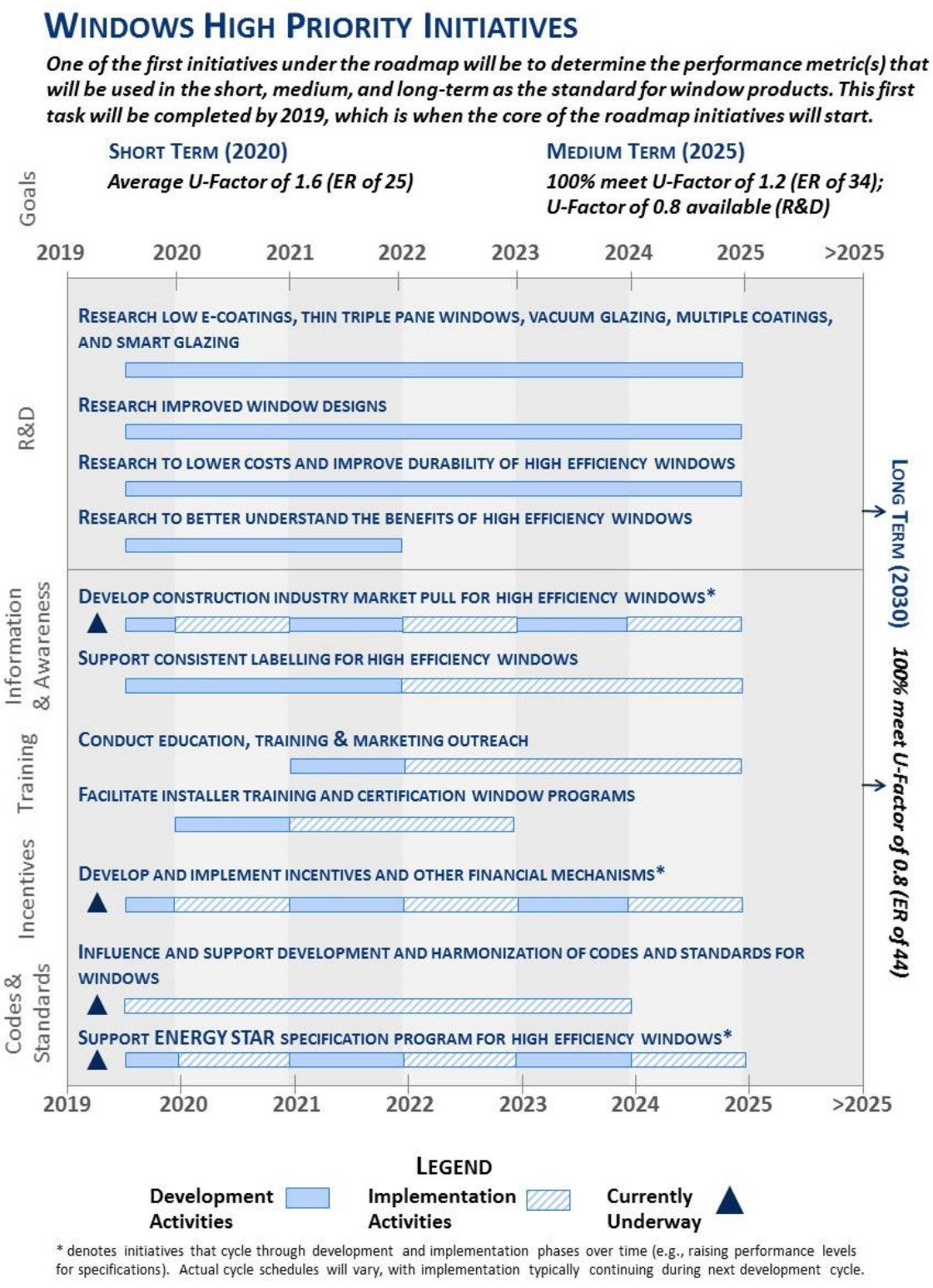
The following figure shows the high priority R&D and deployment initiatives identified through the road mapping process for window technologies to address the technical and market barriers identified in Table 3-1. Initiatives ranked as lower priority are not included in the road map, but their descriptions can be found in Appendix 7.5.

Governments also recognize that a robust compliance system for minimum energy performance standards is important. While not addressed in the road map, Governments are developing a national compliance strategy as part of federal efforts to regulate residential windows.

U-factor and ER Approach

The approach taken with **U-factor and ER** will impact the types of barriers faced in the market, and the way that the R&D and deployment initiatives will be positioned to drive the market to adopt products that meet the long-term energy performance goals. Building off market research completed over the past few years on the attributes and trade-offs of each metric, one of the first initiatives under the road map will be to determine the performance metric(s) that will be used in the short, medium, and long-term as the standard for window products. This first task will be completed in 2019, which is when the core of the road map initiatives will start. NRCan will work in partnership with provincial and territorial governments and consult with stakeholders in determining the approach, to ensure the market is clear on which performance metric to adopt.

Figure 3-4 Timeline of R&D and Deployment Initiatives for Windows



3.3.1 R&D initiatives for window technologies

The following section provides detail on the high priority R&D initiatives for window technologies. These R&D initiatives could be used to inform NRCan's funding decisions starting as early as 2019-2020. These technologies could be included in the scope of priority areas in future calls for project proposals under the Energy Innovation Program. In carrying out R&D initiatives, NRCan would seek partnerships with stakeholders (in particular Canadian manufacturers) and would consider funding external organizations to undertake independent research.

WINR&D1 – Research low e-coatings, thin triple pane windows, vacuum glazing, multiple coatings, and smart glazing

Researchers and manufacturers are developing window technologies such as advanced coatings, thin triple pane windows, vacuum glazing, aerogel fills, and "smart" or dynamic glazing that could improve the energy efficiency and performance of the next generation of residential windows. Stakeholders should conduct R&D into these emerging technologies, including a review of existing research that is available. Research should also include development of test protocols, standardized performance evaluation procedures for smart/dynamic and other innovative glazing options. Furthermore, installation techniques for these new products could also be researched and understood in order to successfully commercialize these products. This initiative would benefit from coordination with the U.S. and international partners, such as the U.S. Department of Energy (DOE)[10] and Lawrence Berkeley National Laboratory (LBNL).[11]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Manufacturer organizations, provincial and territorial governments.

WINR&D2 – Research improved window designs

The performance of the entire window system impacts the energy savings from high efficiency window technologies, and inefficiencies in the window frame or installation techniques could lower overall performance. Stakeholders should conduct research to improve window design, including opportunities to decrease thermal bridging and other design factors that affect window performance as a whole system. This research should also consider installation techniques to better integrate the window into the building envelope for the range of housing types and age of housing stock available across the country. A focus could also be placed on the retrofit market, which has the highest potential for efficient windows. This initiative would benefit from coordination with the U.S. and international partners, such as the U.S. DOE[12] and LBNL.[13]

[10] U.S. DOE BTO Emerging Technologies – Windows and Building Envelope. Accessed June 2018. Available at: https://www.energy.gov/eere/buildings/windows-and-building-envelope
[11] LBNL – Windows and Daylighting. Accessed June 2018. Available at: https://windows.lbl.gov/
[12] U.S. DOE BTO Emerging Technologies – Windows and Building Envelope. Accessed June 2018. Available at: https://www.energy.gov/eere/buildings/windows-and-building-envelope
[13] LBNL – Windows and Daylighting. Accessed June 2018. Available at: https://windows.lbl.gov/

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Manufacturer organizations, provincial and territorial governments.

WINR&D3 – RESEARCH TO LOWER COSTS AND IMPROVE DURABILITY OF HIGH EFFICIENCY WINDOWS

New window technologies could offer improved comfort and energy savings, but could carry increased upfront costs and durability concerns that lower their affordability and market acceptance. Stakeholders should conduct research into lowering the costs, and improving durability, of high efficiency glazing, improved framing materials and more efficient designs to increase accessibility for customers. This initiative would benefit from coordination with the U.S. and international partners, such as the U.S. DOE[14] and LBNL.[15]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Manufacturer organizations, provincial and territorial governments.

WINR&D4 – RESEARCH TO BETTER UNDERSTAND THE BENEFITS OF HIGH EFFICIENCY WINDOWS

Researchers, manufacturers, and other stakeholders must find the right balance between high efficiency, product cost, and installation requirements to ultimately achieve wider success of high efficiency windows. Stakeholders should conduct research to better understand the economic paybacks, performance efficiencies, durability enhancements, as well as comfort and non-energy benefits associated with high efficiency window products. This research could include both laboratory and field testing as appropriate. This research could help inform initiative WINDEP3, which promotes education, promotion and outreach to improve uptake of high efficiency windows, and WINDEP4, which promotes installer[16] training and certification programs for high efficiency windows.

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, manufacturer organizations.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations.

3.3.2 Deployment initiatives for window technologies

The following section provides details on the high priority deployment initiatives for window technologies. These initiatives could address important market barriers and challenges to increase uptake of high efficiency window technologies into Canadian homes.

[14] U.S. DOE BTO Emerging Technologies – Windows and Building Envelope. Accessed June 2018. Available at: https://www.energy.gov/eere/buildings/windows-and-building-envelope
[15] LBNL – Windows and Daylighting. Accessed June 2018. Available at: https://windows.lbl.gov/
[16] Installer and contractor are used interchangeably.

Information & awareness

WINDEP1 – Develop construction industry market pull for high efficiency windows

Manufacturers wanting to deploy new energy efficient technologies in the construction sector have to overcome the additional barrier of entering a market that is local and fragmented, with many builders and renovators that lack the time and resources to consider the impact of new technologies on their business practice. Builders and renovators know their current approach and are hesitant to try new technologies since they are perceived as adding scheduling, cost, and call-back risks.

NRCan's LEEP program helps regional builder and renovator groups find, select and evaluate the new energy efficient technology solutions that best meet their needs. For manufacturers, LEEP provides opportunities to learn how market leaders see the comparative benefits of different technologies; work with a group of builders that have already become knowledgeable about their technology and have a specific in mind; learn how their technology offering could be adapted to better meet local market needs; and, access a critical mass of builders that could make it cost effective to support a new product in a particular region. Stakeholders should develop regional LEEP initiatives with provincial governments, utilities / efficiency organizations, and home builder associations.

Key Stakeholder Roles:

- Lead Organization: NRCan.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations, home builder associations, contractors, manufacturers.

Key Activities:

- Build partnerships and initiate local initiatives with provincial governments, utilities / efficiency organizations, and home builder associations.
- Work with leading local builders to select the technologies they want to focus on, define the applications they are most interested in, and select the manufacturers they would like to present solutions.
- Host and deliver technology forums with presenting manufacturers, builders, renovators, trades, energy advisors, and local consultants.
- Deliver and document field trials in which builders evaluate their selected technologies in high performance homes.
- Document and share selection process and field trial results, and develop guides that address gaps identified through those field trials.

WINDEP2 – Support consistent labelling for high efficiency windows

Window technologies have several performance rating metrics that describe the key features and energy performance of the products. This information is recorded on the window as a label, and can be used in marketing and sales literature to inform builders, contractors, and consumers. National Building Code, provincial and territorial and local government codes, ENERGY STAR® certification, and high performance building certifications each specify different performance ratings and minimum

criteria for windows.[17] As a result, stakeholders could have difficulty parsing out high efficiency products from baseline products for their region. Stakeholders should improve current window labelling programs, which could support the adoption of high efficiency window products by ensuring standardized labelling for window products is enforced. This would allow stakeholders across the window product value chain to better understand the differences between window products.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments.
- Supporting Organizations: Utilities / efficiency organizations, industry organizations.[18]

Key Activities:

- Review labelling programs and criteria currently in the marketplace and understand how different stakeholders enforce labelling programs and labelling requirements under code.
- Work with provincial and territorial governments to ensure that labelling is standardized across Canada and complemented by high rates of compliance to ensure fair competition.

Training

WINDEP3 – Conduct education, training, and marketing outreach to support adoption of high efficiency windows

Manufacturers of high efficiency window technologies require support to promote their products to builders, contractors, and consumers across Canada. Stakeholders should conduct education, training, and marketing outreach to support the adoption of high efficiency windows. These initiatives would help to improve the understanding of energy and non-energy benefits (cost savings, comfort, reliability etc.) of window products, window labelling programs, window codes and ratings, window installation procedures, and window incentive programs. This initiative would be informed by WINR&D4, which addressed research into the benefits of high efficiency windows.

Key Stakeholder Roles:

- Lead Organizations: Manufacturers, utilities / efficiency organizations, industry organizations.
- Supporting Organizations: NRCan, provincial and territorial governments.

Key Activities:

- Based upon previous education, training and marketing outreach activities, identify and document all lessons learned. This would include understanding what educational materials are currently not in the marketplace and are most suitable to drive high efficiency window adoption, and understanding whether different geographies require different types of outreach materials.

[17] The ENERGY STAR name and symbol are trademarks registered in Canada by the United States Environmental Protection Agency and are administered and promoted by Natural Resources Canada.
[18] The generic term "industry organization" is used to mean the following: home builders associations, manufacturer associations, inspector, contractors, and installer associations, utility associations, and other organizations that represent a specific trade or membership involved in the building sector.

- Develop marketing plan, expected results and strategies to deploy education, training and other marketing outreach activities.
- Ensure that sufficient research is undertaken to understand the effectiveness of educational programs to justify the business case for this initiative.
- Work to promote timely deployment of educational materials.
- Track success of the initiative based upon surveys and adoption rates.

WINDEP4 – Facilitate installer training and certification window programs

Transforming the residential windows market in Canada requires coordination with home builders, installation contractors, and other stakeholders who specify, sell, and install windows. Homebuilders, renovators, and installation contractors are generally the first point of contact for consumers regarding window technologies, and high efficiency windows can only provide improved comfort and energy savings if they are installed correctly. Stakeholders should support installer training and certification programs around the next generation of window technologies that could help drive adoption of high efficiency window products by educating the contractors and installers regarding these products and ensuring they can confidently install high efficiency windows for their customers. Utilities / efficiency organizations could consider installer certification as a prerequisite or a bonus for participation incentive programs aimed at the replacement market. This initiative would be informed by WINR&D4, which addressed research into the benefits of high efficiency windows.

Key Stakeholder Roles:

- Lead Organizations: Manufacturer organizations, contractors and installers.
- Supporting Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, home builder organizations.

Key Activities:

- Conduct inventory of what training opportunities and installer certifications are in the marketplace today and their success.
- Identify key training, certification, and education opportunities for Canadian contractors and installers.
- Ensure that there is sufficient installer and contractor buy-in for the new certification program – the topics covered in the training must be applicable, drive high efficiency window adoption and provide value to installers and contractors.
- Work with provincial and territorial governments, utilities / efficiency organizations, and industry organizations to ensure that the roll out of such certifications are coordinated across Canada.

Incentives

WINDEP5 – Develop and implement incentives and other financial mechanisms for high efficiency windows

Canadian manufacturers and other stakeholders require support to market and deploy the next generation of window technologies across Canada. Stakeholders should develop incentives and other financial mechanisms to support key players throughout the window product value chain. Incentives could include a combination of up-stream funding support for manufacturers to re-design and certify window products, mid-stream incentive for contractors and installers, and down-stream incentives for consumers (new and retrofit product incentives, energy audit incentives, on-bill financing options, tax rebates). Utilities / efficiency organizations and provincial and territorial governments already have some of these measures in place. In addition, as part of the Low Carbon Economy Fund (LCEF) the Government of Canada is providing $1.4B to provincial and territorial governments for GHG mitigation programs, including energy efficiency retrofits. Appendix 7.2 provides an overview of existing incentive programs for high efficiency windows by jurisdiction in Canada.

Key Stakeholder Roles:

- Lead Organizations: Provincial and territorial governments, utilities / efficiency organizations.
- Supporting Organizations: NRCan, industry organizations.

Key Activities:

- Assess existing incentive programs across Canada for their alignment with aspirational goals and success in overcoming market barriers.
- Develop or update financial incentives and non-financial incentive programs (e.g., training, awareness) as necessary, with a goal to achieve greater market adoption within each jurisdiction.
- Revisit incentive program on an on-going basis to promote alignment with aspirational goals, and to coordinate with planned regulations.

Codes & standards

WINDEP6 – Influence and support development and harmonization of codes and standards for windows

Windows are a core feature of residential buildings and are subject to requirements defined in reference standards and building code requirements across Canada. Where inconsistencies arise across code jurisdictions, manufacturers, builders, and other parties face uncertainties in developing and deploying new window technologies. To overcome these issues, stakeholders should support efforts by the Canadian Commission in Buildings and Fire Codes to increase the energy efficiency requirements in the National Building Code. This includes supporting the update and development of new standards, as necessary, to maximize harmonization of energy efficiency requirements for windows across Canada. This work would help to ensure that building codes and standards support and are consistent with the aspirational goals in the road map both in terms of timing and level of ambition.

The federal government can also help stakeholders throughout the window product value chain to better understand codes by developing guidelines that describe performance criteria, specification language, code references, and the differences between codes for the retrofit versus new construction market.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, codes and standards organizations.
- Supporting Organizations: Industry organizations, manufacturers.

Key Activities:

- Engage the code development process to raise awareness of the road map and its aspirational goals for energy performance of windows, and advocate for alignment.
- Determine if any performance ratings must be updated to support code process with respect to energy efficiency.
- Work with provincial and territorial governments to promote timely code adoption.
- Track requirements across the country to understand playing field of energy efficiency requirements, and use that information to inform further harmonization efforts.

WINDEP7 – SUPPORT ENERGY STAR SPECIFICATION PROGRAM FOR HIGH EFFICIENCY WINDOWS

Consumers often look for products that carry a specific label or certification when making their purchasing decisions, and this strategy could be useful to designate high efficiency windows that perform well in Canadian climates. Programs like ENERGY STAR®[19] provide information to consumers, but also send a competitive signal to manufacturers to develop new technologies that raise the highest level of performance for the industry. In spring 2018, NRCan updated the Canadian ENERGY STAR specification to align with the medium-term aspirational goal. Stakeholders should continue to support the ENERGY STAR specification program and ENERGY STAR Most Efficient designation and periodically update the performance levels to align with the long-term aspirational goals and product availability.

Challenge specifications should be promoted throughout utility / efficiency organization and industry programs, and supported through market transformation activities like trainings, design guides, recognition and award programs, as well as workshops to share best practices, track market adoption, and refine the specification program.

Key Stakeholder Roles:

- Lead Organization: NRCan.
- Supporting Organizations: Industry organizations, provincial and territorial governments, utilities / efficiency organizations.

[19] NRCan. 2018. "Windows, Doors and Skylights – ENERGY STAR Canada Technical Specification." June 2018. Available at: https://www.nrcan.gc.ca/energy/products/for-participants/specifications/20950

Key Activities:

- Design incentive programs around revised ENERGY STAR specification and Most Efficient designated products to drive market adoption for windows meeting the medium-term aspirational goals.
- Conduct outreach to partner stakeholders to drive participation, track market awareness and adoption in each local market, and highlight successful demonstrations, partnerships, products, etc.
- Review ENERGY STAR Most Efficient designations annually and ENERGY STAR specification periodically. Regularly revise these programs with an eye towards future modifications that would align with long-term aspirational goals.

3.4. Key stakeholder roles for window initiatives

Table 3-2 highlights the key stakeholder roles for priority R&D and deployment initiatives for window technologies.[20] Each initiative requires coordination amongst governments, manufacturer, industry, and utility stakeholders to achieve the short-, medium-, and long-term aspirational goals for energy performance of window technologies in Canada. Stakeholders must provide ongoing support and continued cooperation for deployment efforts to maintain momentum in the marketplace. Section 6 further describes strategies for market deployment success.

Table 3-2 Summary of Stakeholder Involvement for Windows Activities

Activities	Stakeholder Roles and Responsibilities
R&D for Product Development	• NRCan has a lead role to coordinate, support, and guide R&D projects for windows. Provincial and territorial governments, some manufacturer associations, as well as utilities / efficiency organizations also support R&D activities for windows in some jurisdictions where emerging technology programs exists. • Manufacturers, federal laboratories, research organizations or other parties often lead the actual research activities, product development, and information dissemination.

[20] This table summarizes the major activities and roles detailed in the initiative descriptions. The responsibilities and relationship between lead and supporting organizations will vary by initiative.

Activities	Stakeholder Roles and Responsibilities
Information and Awareness	• Governments have a role in supporting a level playing field for different manufacturers through development of test procedures and performance metrics for windows. • Governments and utility / efficiency organizations also support national efforts to develop programs by supporting test standards, calling up certification requirements, and support qualified product lists for windows. • Codes and standards organizations, manufacturers, and industry organizations[21] develop the test procedure. Manufacturers then certify products. • Ongoing activities, e.g. LEEP, labelling, etc., carried out by multiple stakeholders all serve to increase information and awareness.
Training	• Manufacturers, utilities / efficiency organizations, and industry organizations prepare training and education materials for contractors, builders, engineers, inspectors, insurers, and other stakeholders, and develop and deliver installer certification programs.
Incentives[22]	• Provincial and territorial governments and utilities / efficiency organizations have a greater role in creating local demand for high efficiency windows and supporting local contractors, energy advisors, inspectors, and other stakeholders. • Utilities / efficiency organizations have a strong relationship with customers and have supported the adoption of advanced technologies through current incentive programs. These programs would need to adapt over time to accommodate market and technology changes; industry organizations could support by providing their insights and expertise.
Codes & Standards	• Governments, manufacturers, and industry organizations gather the information necessary to influence and support changes to codes, standards and practices as they relate to windows. Codes and standards organizations implement changes where necessary. • Governments develop high performance specifications, such as ENERGY STAR, to support both consumer awareness and manufacturer development of higher performance products. Manufacturers and industry organizations provide technical support to define and/or inform performance levels and program requirements.

[21] The generic term "industry organization" is used to mean any of the following: home builders associations, manufacturer associations, inspector, contractors, and installer associations, utility associations, and other organizations that represent a specific trade or membership involved in the building sector.

[22] Appendix 7.2 provides an overview of existing incentive programs for high efficiency windows by jurisdiction in Canada.

Table 3-3 outlines each of the initiatives identified for window technologies and cross references them with the 5A's framework. While each initiative can support several of the 5A's, only the key ones have been identified below. This table is intended to provide additional context regarding the barriers that have been identified above.

Table 3-3 Key Barriers Addressed by Residential Window Initiatives

Initiative #	Initiative Name	Availability	Accessibility	Awareness	Affordability	Acceptance
WINR&D1	Research low e-coatings, thin triple pane windows, vacuum glazing, multiple coatings, and smart glazing.	●				
WINR&D2	Research improved window designs.	●			●	
WINR&D3	Research to lower costs and improve durability of high efficiency windows.	●			●	
WINR&D4	Research to better understand the benefits of high efficiency windows.			●		●
WINDEP1	Develop construction industry market pull for high efficiency windows.		●	●		●
WINDEP2	Support consistent labelling for high efficiency windows.			●		●
WINDEP3	Conduct education, training, and marketing outreach to support adoption of high efficiency windows.			●		●
WINDEP4	Facilitate installer training and certification window programs.			●		●
WINDEP5	Develop and implement incentives and other financial mechanisms for high efficiency windows.			●	●	
WINDEP6	Influence and support development and harmonization of codes and standards for windows.		●	●		
WINDEP7	Support ENERGY STAR® specification program for high efficiency windows.	●	●	●		

4. SPACE HEATING

This section contains a R&D and deployment road map for residential and commercial space heating equipment and systems.[23] This section also discusses combination space-and-water-heating systems that serve both end-uses through a single appliance or system.

4.1. Technology description

Space heating systems maintain comfortable indoor temperatures during the Canadian heating season by generating and distributing heating energy throughout the building. Space heating is the largest source of energy consumption in Canada's building sector. It accounts for 64% of energy consumed in homes and 56% of energy consumed in commercial buildings.[24]

A variety of space heating systems are available in Canada and are generally classified by their technology type, distribution type, fuel type, and other parameters. Current Canadian buildings primarily use natural gas and propane for space heating (64%), with electricity (18%), fuel oil (6%), and other heating fuels such as biomass (12%) accounting for a smaller share of the market. Today, virtually all residential gas-fired heating equipment for sale are condensing technology (>90% efficiency), and 10% of sales of electrical systems are heat pumps.[25] The following list provides examples for space heating system in use in Canada:

- Technology type: furnace, boiler, air-source heat pump[26], ground source heat pump, electric resistance;
- Distribution type: radiant, ducted, ductless, baseboard/zonal; and
- Fuel source: natural gas, propane, oil, electricity, solar.

The energy performance of space heating is measured differently based on the type of heating equipment. A summary of the metrics used to measure space heating performance is contained in Figure 4-1 below.

[23] This road map focuses on improving the energy efficiency of space heating equipment and systems to reduce site energy consumption, and does not evaluate source energy consumption and emissions, which vary by location across Canada.
[24] NRCan. 2014. National Energy End-Use Database.
[25] NRCan. 2017. "Market transformation strategies for energy-using equipment in the building sector." August 2017. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf
[26] Air-source heat pumps with design features that allow for efficient performance in low temperatures are often designated as "cold climate" based on their high coefficient of performance (COP), heating season performance factor (HSPF), or seasonal coefficient of performance (SCOP) ratings.

Figure 4-1 Space Heating Energy Performance Measurements

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

- *The heating coefficient of performance (COP) is the ratio of the useful heat provided by the system per unit of energy. The COP will vary depending on the ambient temperature condition.*
- *The heating season performance factor (HSPF) or seasonal coefficient of performance (SCOP) gives an indication of how efficient the heat pump system is over the entire heating season. This takes into account the performance of the system at different ambient temperature conditions and thus will vary depending on the climate region.*

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).

In addition, heat pumps with design features that allow for efficient performance in low temperatures are often designated as "cold climate" based on their high COP, HSPF, or SCOP ratings.

Condensing technologies, ground-source heat pumps (GSHPs), cold climate air-source heat pumps (CCHPs), gas heat pumps (e.g. absorption, engine driven and thermal compression technologies), and other advanced technologies (e.g., solar thermal, micro combined heat and power (mCHP), etc.) will be important contributors to achieving the Governments' aspirational goals for space heating. Nevertheless, these technologies require R&D and deployment actions to address their unique barriers to successful market adoption.

Figure 4-2 highlights the Governments' short-, medium-, and long-term aspirational goals for energy performance of space heating technologies. The aspirational goals cover residential and commercial technologies that use natural gas and electricity; and include R&D targets that support the development of next generation technologies.[27] They recognize the range of heating systems and fuel types used today and the challenges within the existing building market; and the fact that different regions of the country have unique geography, different energy costs, emission intensity of the grid and available fuel sources. For these reasons, they include multiple pathways to meet energy performance targets.

These aspirational goals outline a transition to heat pump technologies that are capable of operating in cold temperatures for electric heating (e.g. air-source CCHP, GSHP), and for fuel-fired heating, the transition to condensing and heat pump technologies (e.g. absorption, engine driven and thermal compression gas heat

[27] 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 road map. The future role of baseboards and other secondary heating technologies will be evaluated when the road map is updated.

pumps). The aspirational goals also seek to ensure that barriers are not inadvertently created for the use of biomass and other renewable technologies in remote and northern applications.

Figure 4-2 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.*[28]

***Medium term**: By 2030,*

- *A residential natural gas heat pump with a SCOP greater than 1.2 can be manufactured and installed cost-effectively (R&D target).*[Error! Bookmark not defined.]
- *A residential cold climate air-source heat pump with a SCOP greater than 2.75 can be manufactured and installed cost-effectively (R&D target).*[29]
- *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%.*

[28] For American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Region V, when tested according to the CSA Express document (currently in draft form) regarding variable capacity heat pumps.

[29] The R&D 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 road map.

4.2. Key technical and market challenges

Table 4-1 outlines key barriers for space heating technologies. Barriers have been broken into technical barriers, and market barriers, respectively.

Table 4-1 Technical and Market Challenges and Barriers

	Challenge / Barrier	Description
Technical	**Performance at Low Ambient Temperatures**	Few air-source heat pump products meet the 2025 performance goals, and none are sized for commercial buildings. While available globally, gas heat pumps for space heating are not fully commercialized in Canada.
	Test Procedures and Performance Ratings	There is no standardized test procedure to rate energy performance of air-source heat pumps, gas heat pumps and combination space and water heat pumps at low temperatures. A limited number of facilities in North America are capable of testing and rating performance in cold climates.
	High Cost for Ground Loops	GSHPs offer one of the higher space heating system efficiencies; however, the systems carry high upfront costs and installation complexity for the ground loops, which poses barriers to their greater adoption, particularly in retrofit applications.
	Retrofit Challenges	Combination space and water heating systems may impose an additional incremental cost in a retrofit setting if the end user need to replace components of the existing system early. For heat pumps displacing energy use from a primary system, the right controls need to be used to ensure high overall system performance.
	Building Stock Variation	For commercial buildings in particular, each building requires a slightly different space heating design and there are many technology, equipment, and system configurations that could be deployed depending on the requirements of the building. The buildings work as a system, and the efficiency depends on the selected equipment and how they work as a system.
	Remote and Northern Communities	Remote and northern communities have challenging space heating requirements based on higher heating loads, fuel availability, and other unique circumstances. The high efficiency options discussed in the road map may have limitations in these regions, but increased adoption of biomass and renewable heating sources could be an attractive alternative in some cases.
Market	**Product Availability**	Few manufacturers offer commercial condensing furnaces in Canada, limiting the accessibility of products to building owners.
	Training for Contractors / Inspectors	Engineering service providers, contractors, and building owners have limited experience and knowledge of the design, installation, commissioning and other aspects of advanced space heating systems. New technologies carry additional installation, operations, and maintenance requirements for contractors, design engineers, and building owners.

	Challenge / Barrier	Description
Market	**Higher Upfront Cost**	High efficiency technology carries higher upfront costs, which could be a disincentive to adoption, especially for homeowners with a limited budget and building owners who do not pay utility bills. Low gas and electricity rates could also lead to unreasonably long payback periods.
	Awareness of Technologies	Early electric cold climate air-source heat pump models underperformed relative to contractor and homeowner expectations and there is still lingering skepticism for the current generation of products.
	Requirements for Backup Heating	In some areas, building inspectors and insurers require backup gas-fired or electric resistance heating systems due to reliability and performance concerns about heat pumps operating as the primary space heating system in Canadian climates.

Figure 4-3 summarizes the current technology and market status for high efficiency space heating technologies in "5A's framework".

Figure 4-3 5A's for Space Heating Technologies

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	🟢	🟡	🟡	🟡	🟢
Ground-source heat pumps	🟢	🟢	🟢	🔴	🔴
Cold climate air-source heat pumps	🟡	🟡	🟡	🟡	🟡
Gas heat pumps	🟡	🔴	🔴	🔴	🔴

🟢 Yes 🔴 No 🟡 To some extent

4.3. Road map for space heating technologies

The following figures show the high priority R&D and deployment initiatives identified through the road mapping process for electric heat pumps (CCHP and GSHP), gas heat pumps, and other advanced technologies to address the technical and market barriers identified above. Initiatives ranked as lower priority are not included in the road map, but their descriptions can be found in Appendix 7.5.

Condensing commercial gas furnaces are also an important consideration for commercial buildings. NRCan will continue to implement its workplan for advancing the adoption of these units in Canada, including: updating the Canadian Standards Association (CSA) P.8 standard to be more reflective of Canadian climate conditions; examining the benefits of hybrid rooftop units with both heat pump and gas-fired heating, and advancing demonstration projects to build more confidence in the market around installation and operation. For these reasons, they are not directly addressed in the road map initiatives below.

Figure 4-4 Timeline of R&D Initiatives for Space Heating

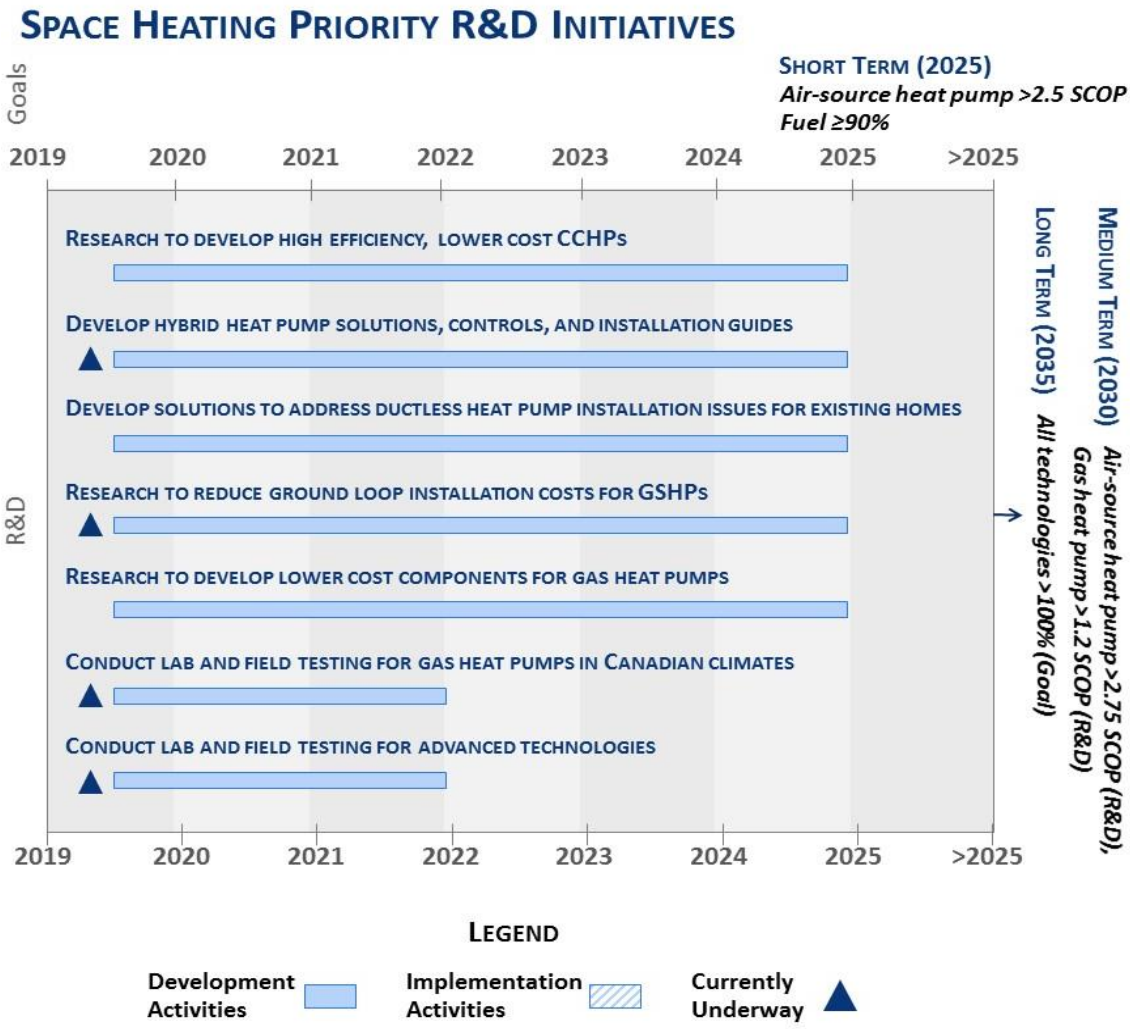
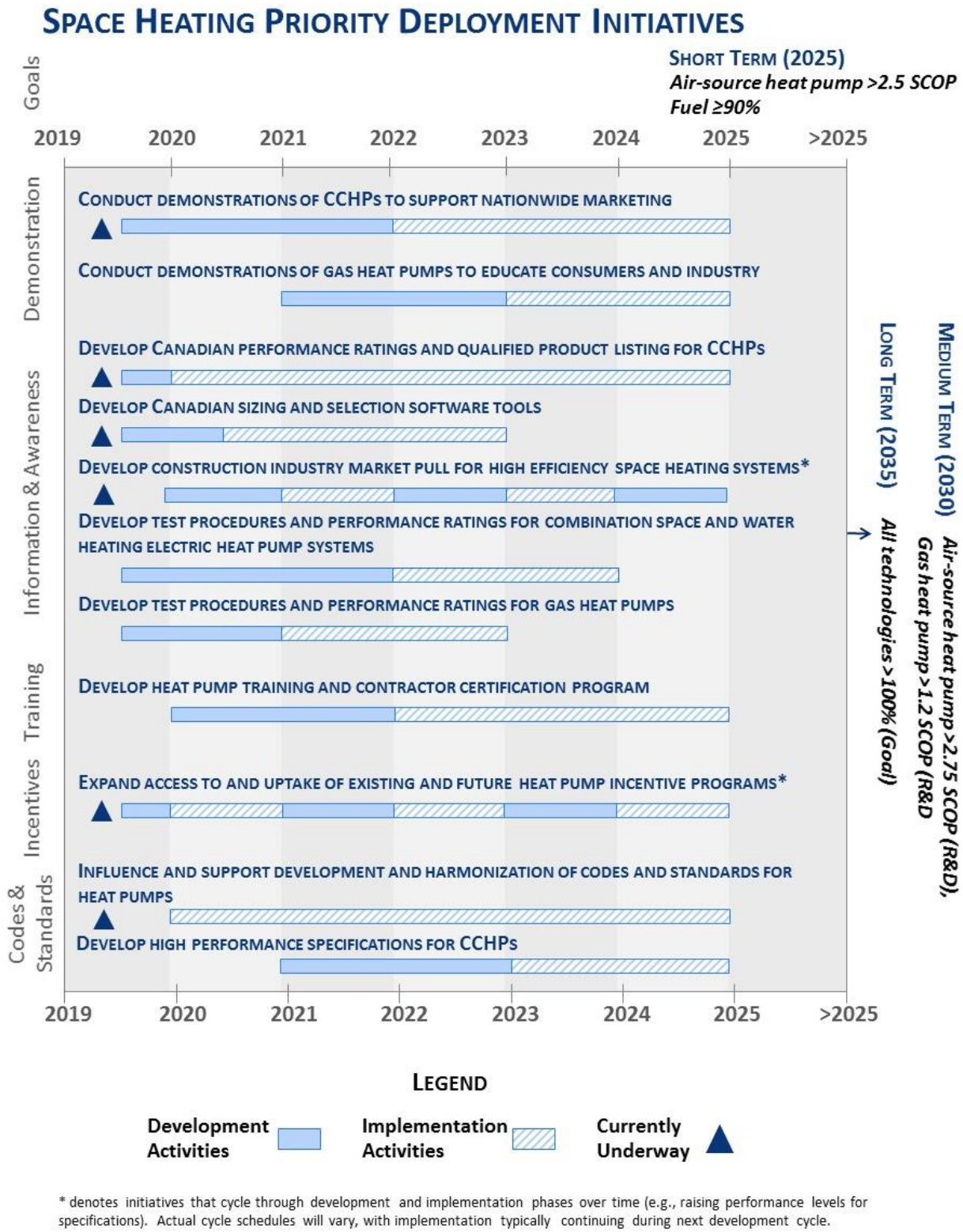


Figure 4-5 Timeline of Deployment Initiatives for Space Heating



* denotes initiatives that cycle through development and implementation phases over time (e.g., raising performance levels for specifications). Actual cycle schedules will vary, with implementation typically continuing during next development cycle.

4.3.1 R&D initiatives for space heating technologies

The following section provides detail on the high priority R&D initiatives for space heating technologies. These R&D initiatives could be used to inform NRCan's funding decisions starting as early as 2019-2020. These

technologies could be included in the scope of priority areas in future calls for project proposals under the Energy Innovation Program. In carrying out R&D initiatives, NRCan would seek partnerships with stakeholders (in particular Canadian manufacturers) and would consider funding external organizations to undertake independent research.

SHR&D1 – Research to develop high efficiency, lower cost CCHPs

Focus: Residential and commercial buildings

Manufacturers offer a range of heat pumps today that can operate efficiently down to temperatures of -10°C and below, but further R&D could improve the performance of products in Canadian climates, avoid the use of high global warming potential (GWP) refrigerants, reduce their incremental cost and minimize their impact on the electric grid. Stakeholders should conduct laboratory and field research on the next generation of CCHPs to evaluate advanced compressors, improved defrost cycles, new refrigerants and other attributes. This research would help guide manufacturer R&D programs and provide valuable information for market deployment initiatives.

This initiative would benefit from coordination with the U.S. and international partners. Organizations such as U.S. DOE[30], leading global manufacturers, and international research organizations such as International Energy Agency (IEA) Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) could work together to develop the next generation of high efficiency, low cost CCHPs.[31]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Provincial and territorial governments, manufacturer organizations, utilities / efficiency organizations.

SHR&D2 – Develop hybrid heat pump solutions, controls, and installation guides

Focus: Residential and commercial buildings

Manufacturers have developed dual-fuel or hybrid heat pump solutions that could operate as either a gas-fired furnace or electric heat pump, depending on the outdoor conditions and electricity rates. The electric heat pump operates as the primary heating system during moderate heating loads, and the gas furnace operates during colder conditions when the heat pump capacity and efficiency may decrease. Hybrid systems could reduce GHG emissions from homes and buildings in some jurisdictions, without adverse effects on the electrical utility.

These technologies may provide a practical solution for many Canadian climates, but should be evaluated against other cold climate solutions to inform R&D and deployment efforts. NRCan has analyzed hybrid heat pumps for Canadian homes and conducted field testing with utility, builder, manufacturer, and research partners.[32] In particular, NRCan has identified the need for further research on controls for integrating two different heating systems, particularly around fuel pricing, automated controls for time-of-day, weather, utility prices, and other signals. MaRS Advanced Energy Centre and Enbridge Gas recently analyzed different hybrid heating solutions relative to gas-only and electric-only options, and also identified controls strategies as a key research need.[33] Stakeholders should continue to assess the potential of hybrid heat pumps in Canadian markets and develop smart controls for optimum performance, utility savings, and grid-interactive

[30] U.S. DOE BTO Emerging Technologies – HVAC, Water Heating, and Appliances. Accessed May 2018. Available at: https://www.energy.gov/eere/buildings/hvac-water-heating-and-appliances
[31] IEA Heat Pumping Technologies. Accessed May 2018. Available at: http://heatpumpingtechnologies.org/
[32] CanmetENERGY. 2017. "Opportunities for Hybrid Heating Systems." Workshop summary, November 29, 2017.
[33] MaRS Discovery District. "Future of Home Heating." April 2018. Available at: https://www.marsdd.com/wp-content/uploads/2018/04/FoHH-VF.pdf.

features. In addition, stakeholders should create installation guides and procedures to ensure that installers and contractors can deliver hybrid systems that save energy and emission, and meet customer expectations. CanmetENERGY is currently working on hybrid rooftop heating systems for buildings, which can serve as a starting point for future initiatives in the commercial side of the sector.

This initiative could support the initiative to expand the access to and uptake of existing and future heat pump incentive programs (SHDEP9).

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, utilities / efficiency organizations, industry organizations[34], manufacturers.
- Supporting Organizations: Builders, provincial and territorial governments.

SHR&D3 – Develop solutions to address ductless heat pump installation issues for existing homes

Focus: Residential buildings

Ductless heat pumps offer a high efficiency option to retrofit homes with existing space heating systems. They can provide excellent zoning capabilities particularly as supplementary heating systems, but may go underutilized due to installation costs and issues with maintaining occupant comfort. Stakeholders should explore ways to reduce installation complexity for electric ductless heat pumps such as reducing electrical infrastructure upgrade costs, optimizing layout for even heating distribution with legacy systems, and developing design and installation guidelines for interfacing heat pumps with legacy heating systems, including controls and connectivity. The outcome of this research could support contractor training materials as well as high performance building design guides. This initiative will help inform the development of heat pump training and contractor certification programs (SHDEP8).

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, manufacturers, utilities / efficiency organizations.
- Supporting Organizations: Provincial and territorial governments, contractors.

SHR&D4 – Research to reduce ground loop installation costs for GSHPs

Focus: Residential and commercial buildings

GSHPs have a long history of efficient performance, even in cold climates. Nevertheless, the market acceptance of this technology is inhibited by several factors, most notably the larger upfront cost for installing the ground loops. GSHP installation involves either excavation of a wide area with shallow loops, or more limited deeper drilling locations, which greatly increases their installation costs relative to more conventional furnace, boiler, and air-source / water-source heat pump options. District heating systems may offer a solution to share the ground loop cost over a large number of buildings. Stakeholders should conduct research and perform field studies to identify ways to reduce GSHP installation costs.

While outside of R&D activities, another strategy to reduce ground loop installation costs is to reduce financial, logistics, overhead costs for installers. For example, Enbridge Gas is currently exploring a program through which the utility / efficiency organization offers to finance the installation of ground loops for

[34] The generic term "industry organization" is used to mean the following: home builders associations, manufacturer associations, inspector, contractors, and installer associations, utility associations, and other organizations that represent a specific trade or membership involved in the building sector.

homebuilders.[35]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations.

SHR&D5 – Research to develop lower cost components for gas heat pumps

Focus: Residential and commercial buildings

Gas heat pumps have limited market acceptance globally, with size, weight, cost, and other adoption issues constraining the advancement of the technology. Some gas heat pumps use an absorption or other thermally activated heat pump cycle, and have large, complex, and expensive heat exchangers to effectively transfer heat and safely accommodate toxic and/or corrosive refrigerants. Stakeholders should conduct laboratory research to develop the next generation of heat exchangers and other components for gas heat pumps that offer high efficiency at lower cost, weight and size.

This initiative would benefit from coordination with the U.S. and international partners. Organizations such as U.S. DOE[36], leading global manufacturers, and international research organizations such as IEA HPT TCP could work together to develop the next generation of high efficiency, low cost heat pumps.[37]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, manufacturers.
- Supporting Organizations: Industry organizations.

SHR&D6 – Conduct lab and field testing for gas heat pumps in Canadian climates

Focus: Residential and commercial buildings

Gas heat pumps offer the opportunity for space heating efficiencies greater than 100% for gas-fired appliances. Current products under development are expected to achieve efficiencies of 140% and greater without suffering from limited capacity and efficiency degradation in the coldest conditions. Stakeholders should conduct laboratory and field testing in Canadian climates, including extreme winter testing to -20°C and -40°C. The laboratory and field testing would help to characterize product performance and encourage wider field testing and product demonstrations. The results of field testing will determine how broader demonstrations should be developed (SHDEP2).

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers, utilities / efficiency organizations.
- Supporting Organizations: Provincial and territorial governments.

[35] Nagy, Bruce. 2017. "Enbridge Eyes Geothermal Future." Plumbing + HVAC. April 25, 2018. Available at: http://plumbingandhvac.ca/enbridge-eyes-geothermal-future/

[36] U.S. DOE BTO Emerging Technologies – HVAC, Water Heating, and Appliances. Accessed May 2018. Available at: https://www.energy.gov/eere/buildings/hvac-water-heating-and-appliances

[37] IEA Heat Pumping Technologies. Accessed May 2018. Available at: http://heatpumpingtechnologies.org/

SHR&D7 – CONDUCT LAB AND FIELD TESTING FOR ADVANCED TECHNOLOGIES

FOCUS: RESIDENTIAL AND COMMERCIAL BUILDINGS

Advanced technologies (e.g., solar thermal, mCHP, seasonal thermal storage) combined with high efficiency space heating systems could increase the energy savings for consumers, but limited information exists on system performance in Canadian climates and building markets. NRCan and some utilities / efficiency organizations have supported the development of mCHP[38] and solar thermal systems[39] in recent years, and are currently exploring new technologies in these research areas, including a residential mCHP demonstration in Alberta.[40] Stakeholders should conduct a series of laboratory and field tests to evaluate the performance and efficiency of these advanced systems and understand their prospects for further R&D and market support. The results of field testing will determine if broader demonstrations are necessary.

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, manufacturers, utilities / efficiency organizations.
- Supporting Organizations: Provincial and territorial governments.

4.3.2 Deployment initiatives for space heating technologies

The following section provides detail on the high priority deployment initiatives for space heating technologies. These initiatives could address important market barriers and challenges to increase uptake of high efficiency space heating technologies into Canadian homes and buildings.

Demonstration

SHDEP1 – CONDUCT DEMONSTRATIONS OF CCHPS TO SUPPORT NATIONWIDE MARKETING

FOCUS: RESIDENTIAL BUILDINGS

CCHPs are emerging in most Canadian regions, but more information is required to boost market awareness and confidence in performance and efficiency in cold climates. Stakeholders should conduct an extensive demonstration program with CCHPs to measure the space heating performance, energy efficiency, utility cost savings, installation cost, occupant comfort, and other attributes. CanmetENERGY[41], the Canadian Centre for Housing Technology[42], utilities / efficiency organizations, and other stakeholders have conducted pilots and demonstrations to prove the performance, energy savings, and non-energy benefits, while also exploring their impact on local utility grids. Many of these research efforts have continued as new technologies enter the market.[43] A new series of demonstrations would build on past success and focus on increasing confidence in the business case for CCHPs and showing that the technology works in a variety of situations. Where applicable, utilities / efficiency organizations could monitor the performance of incentivized systems, or pursue less invasive data collection on past incentive program participants by performing billing analyses.

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[38] NRCan. 2018. "Thermoacoustic Cogeneration Engine Development." February 2018. Available at: https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16078

[39] NRCan. 2017. "Plug & Play Building-Integrated Photovoltaic and Thermal (BIPV-T) Technologies." May 2017. Available at: https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16076

[40] Bioenergy international. 2018. "SAIT awarded funding to demonstrate residential micro-CHP retrofit in Alberta." January 2018. Available at: https://bioenergyinternational.com/heat-power/sait-awarded-funding-demonstrate-residential-micro-chp-retrofit-alberta

[41] Kegel et al. 2017. "Performance Testing of Cold Climate Air Source Heat Pumps." NRCan CanmetENERGY. 12th IEA Heat Pump Conference 2017. Available at: http://hpc2017.org/wp-content/uploads/2017/05/O.1.6.4-Performance-Testing-of-Cold-Climate-Air-Source-Heat-Pumps.pdf

[42] Canadian Centre for Housing Technology. Accessed May 2018. Available at: http://www.ccht-cctr.gc.ca/eng/

[43] In spring 2018, NRCan released an expression of interest for demonstrations of CCHPs across Canada, with a planned start by late 2018.

Using the insights gained from the demonstration projects, stakeholders could develop marketing and educational materials in support of consumer and end user awareness campaigns. Marketing is a key element of delivering deployment activities and this research would support marketing, education, and other materials that could improve education to homeowners, landlords, and building owners, and overcome barriers to adoption based on unfamiliarity and uncertain performance. This program would support existing energy efficiency efforts in Atlantic provinces, Ontario, and regions that have experienced increased heat pump adoption. This initiative would also benefit from the creation of a Canadian heat pump centre that serves as a central repository of information on the use of heat pumps for manufacturers, industry organizations, contractors, consumers, and other parties.

In addition, this demonstration program could support other high priority initiatives, by showcasing products meeting the high performance specifications (SHDEP11), products meeting performance goals (SHDEP3), developing construction industry and market pull (SHDEP5) and electric heat pumps serving as combination space and water heating systems (SHDEP6).

Key Stakeholder Roles:

- Lead Organizations: NRCan, utilities / efficiency organizations, provincial and territorial governments.
- Supporting Organizations: Industry organizations, manufacturer, builders, contractors.

Key Activities:

- Develop demonstration research plan, including types of CCHPs, locations, monitoring strategy, recruitment, etc. as well as marketing and communication strategy.
- Conduct outreach to identify participating demonstration sites, install CCHPs and monitoring equipment at demonstration sites, and consider following up with homeowners who have previously installed systems.
- Conduct a consumer satisfaction survey with demonstration participants to understand their experiences with the technologies over time.
- Publish research report, and other materials and incorporate findings into program, marketing, and other activities.
- Develop centralized repository for Canadian information on heat pumps for use by industry and consumers.

SHDEP2 – Conduct demonstrations of gas heat pumps to educate consumers and industry

Focus: Residential and commercial buildings

The heating efficiency and capacity of gas heat pumps does not degrade like that of electric products at low ambient temperatures and gas heat pumps offer other benefits to building owners, like high efficiency water heating. Stakeholders should conduct demonstration projects in residential and commercial buildings in various Canadian regions to demonstrate the performance, energy savings, cost savings, and non-energy benefits of gas heat pumps for multiple end uses. Demonstration would help stakeholders to better understand energy savings compared to a baseline, and identify installation and control requirements for these products. In addition, the demonstrations could provide insights into market acceptance and non-energy benefits, such as customer comfort, installation, service requirements, and reliability concerns. This information would support greater education and outreach efforts by manufacturers, utilities / efficiency organizations, design engineers, and contractors to raise awareness of gas heat pumps' multiple benefits for Canadian buildings. Some small-scale demonstrations have already been carried out in some jurisdictions (e.g. Toronto), and others are being planned (e.g. British Columbia). This initiative will be informed by lab and field testing of gas heat pumps described in initiative SHR&D6.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations.
- Supporting Organizations: Manufacturers, industry organizations, builders, contractors.

Key Activities:

- Develop demonstration research plan, including types of gas heat pumps, locations, monitoring strategy, etc. as well as marketing and communication strategy.
- Conduct outreach to identify participating demonstration sites and schedule installations.
- Install gas heat pumps and monitoring equipment at demonstration sites, and analyze data.
- Conduct a consumer satisfaction survey with demonstration participants to understand their experiences with the technologies over time.
- Publish research report, and other materials and promote to stakeholder groups and wider distribution.

Information & awareness

SHDEP3 – Develop Canadian performance ratings and qualified product listing (QPL) for CCHPs

Focus: Residential buildings

Manufacturers offer heat pumps that can perform efficiently in Canadian climates, but the current efficiency rating system and labelling requirements do not clearly communicate the technology's performance to building designers, contractors, and consumers. Stakeholders should develop an efficiency rating system to measure performance in cold climates, and highlight improved performance at very low temperatures. There are efforts underway to update these test procedures, including a CSA Express Document (CSA EXP07) for variable capacity air-source heat pumps. These activities may involve laboratory testing that simulates different climate regions to confirm that the performance ratings represent real world conditions. These performance ratings would help establish a list of qualified equipment so utilities / efficiency organizations could move towards adopting the test procedures, ratings, and equipment list as part of their energy efficiency programs that reward higher incentives for cold climate performance characteristics. This initiative will be informed by demonstrations of CCHPs to support nationwide marketing (SHDEP1).

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, codes and standards organizations.
- Supporting Organizations: Industry organizations, manufacturers.

Key Activities:

- Publish final test procedure, develop certification protocols including the need for lab testing and begin certifying CCHPs to the test procedure.
- Prepare publicly available list of qualified CCHPs and establish performance criteria for utility / efficiency organization programs using the qualified product lists.
- Revisit utility / efficiency organization incentive programs once the QPL is available, to ensure alignment.

SHDEP4 – Develop Canadian sizing and selection software tools

Focus: Residential buildings

Contractors rely on a combination of experience, on-site measurements, and manufacturer recommendations when designing and sizing a replacement space heating system. Equipment sizing and selection of major technologies and components is an often overlooked aspect of building design that can significantly impact the proper performance and efficiency of space heating systems. Software tools could support contractors, but they must be up-to-date with the latest equipment designs and developed with Canadian climate regions in mind. Stakeholders should review the current status of space heating sizing and selection software for Canadian contractors and building designers, and assess whether upgrades or new software is needed. This research would build on current efforts by FortisBC, BC Hydro, and BC Ministry of Energy Mines & Petroleum Resources on sizing and installation practices for air-source heat pumps in retrofit applications. In addition, CanmetENERGY is currently developing a sizing guide for residential applications. This initiative will help inform the development of heat pump training and contractor certification programs (SHDEP8).

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations,

manufacturers.

- Supporting Organizations: Contractors, home builder associations, codes and standards development organizations (e.g. CSA F280), industry organizations.

Key Activities:

- Review space heating sizing and selection procedures and assess whether available software and tools are able to accommodate the range of climate conditions, technologies, etc. for Canadian market.
- Work with manufacturers and industry organizations to update tools, software, and education materials and promote to contractors.

SHDEP5 – DEVELOP CONSTRUCTION INDUSTRY MARKET PULL FOR HIGH EFFICIENCY SPACE HEATING SYSTEMS

FOCUS: RESIDENTIAL BUILDINGS

Manufacturers wanting to deploy new energy efficient technologies in the construction sector have to overcome the additional barrier of entering a market that is local and fragmented, with many builders and renovators that lack the time and resources to consider the impact of new technologies on their business practice. Builders and renovators know their current approach and are hesitant to try new technologies since they are perceived as adding scheduling, cost, and call-back risks.

NRCan's LEEP program helps regional builder and renovator groups find, select and evaluate the new energy efficient technology solutions that best meet their needs. For manufacturers, LEEP provides opportunities to learn how market leaders see the comparative benefits of different technologies; work with a group of builders that have already become knowledgeable about their technology and have a specific application in mind; learn how their technology offering could be adapted to better meet local market needs; and, access a critical mass of builders that could make it cost effective to support a new product in a particular region. Stakeholders should develop regional LEEP initiatives with provincial governments, utilities / efficiency organizations, and home builder associations. The CCHP demonstrations described in SHDEP1 could also support this initiative.

Key Stakeholder Roles:

- Lead Organization: NRCan.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations, home builder associations, contractors, manufacturers.

Key Activities:

- Build partnerships and initiate local initiatives with provincial governments, utilities / efficiency organizations, and home builder associations.
- Work with leading local builders to select the technologies they want to focus on, define the applications they are most interested in, and select the manufacturers they would like to present solutions.
- Host and deliver technology forums with presenting manufacturers, builders, renovators, trades, energy advisors, and local consultants.
- Deliver and document field trials in which builders evaluate their selected technologies in high performance homes.

- Document and share selection process and field trial results, and develop guides that address gaps identified through those field trials.

SHDEP6 – Develop test procedures and performance ratings for combination space and water heating electric heat pump systems

Focus: Residential buildings

Combination space and water heating systems are an established technology in Canada with fuel-fired boilers and instantaneous water heaters serving as the heating source. As energy efficiency programs and building codes improve the building envelopes in Canadian homes, combination systems could satisfy the smaller thermal loads within the home. Manufacturers have developed similar technologies for electric heat pumps, such that the same outdoor unit satisfies the space and water heating needs for the home. These technologies include air-to-water heat pumps, and air-to-air systems with desuperheaters and may be designed to operate in cold climates. The Canadian CSA P.9 certification provided a test procedure for measuring the performance of fuel-fired combination systems. Stakeholders should develop test procedures and performance ratings for combination electric heat pumps. Further analysis should also be carried out to determine cost and performance targets. This would enable testing and collection of performance data to compare various products and support utility / efficiency organization incentive and education programs, and build on the development of CSA P.9, EXP07, and other heating system standards. This research could also explore necessary control strategies, and thermostats to operate the combination electric heat pump systems. This initiative will be informed by demonstrations of CCHPs to support nationwide marketing (SHDEP1).

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, codes and standards organizations.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Conduct inventory of current test procedures, design guides, performance data, and other materials for combination space and water heating systems, and identify key differences and necessary practices for combination systems using electric heat pumps.
- Develop test procedure and outline key performance targets, cost targets, best practices, installation requirements for optimal performance, efficiency, controls, etc.
- Begin certifying combination heat pumps to the test procedure, and promote the new installation procedures, design, guides, performance metrics, etc. in utility / efficiency organization program marketing and training materials.

SHDEP7 – Develop test procedures and performance ratings for gas heat pumps

Focus: Residential and commercial buildings

Gas heat pumps do not currently have industry-accepted energy efficiency performance ratings. Instead, gas heat pumps have an efficiency curve at different capacities and outdoor temperatures, different operating modes (space heating, space cooling, water heating), and then separate energy consumption values for

natural gas and electricity for auxiliary components (e.g., pumps, fans, etc.). Stakeholders should develop a test procedure to help characterize the performance of gas heat pumps so that stakeholders could evaluate the performance of different products, and project utility consumption in their region. This could ultimately lead to a QPL that could support incentive and other market transformation programs, like high performance specifications.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, codes and standards organizations.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Conduct inventory of current test methods for gas furnaces, electric heat pumps, and related heating, ventilation and air conditioning (HVAC) products.
- Define scope and key requirements of a gas heat pump test procedure(s).
- Develop initial test procedure(s), and conduct laboratory research to evaluate the test procedure(s).
- Begin certifying gas heat pumps to the test procedure(s).

Training

SHDEP8 – Develop heat pump training and contractor certification program

Focus: Residential buildings

CCHPs require specialized installation techniques to achieve their intended performance and efficiency. In addition, consumers rely on contractors as the main source of information for technology selection and comparing energy efficiency options. As a result, heat pumps require unique installation methods, sales strategies, as well as training and certification programs to educate Canadian contractors on the correct sizing, selection, installation, and servicing procedures. Key to this initiative would be collaboration between the Heating, Refrigeration and Air Conditioning Institute of Canada, other contractor organizations and manufacturers to develop training programs and design guides for CCHPs, and regularly updating information to include new topics and technologies (e.g., flammable refrigerants). Utilities and other efficiency organizations could also incorporate these certification and continuing education requirements as part of utility / efficiency organization incentive programs. These efforts would need to build on and respect existing trade training requirements in each province and territory, and may complement existing programs.

Several organizations must work together to provide the necessary level of training: industry organizations to lead training on general best practices, and manufacturers to provide technology specific training on their products. Industry organizations could lead discussions on technology basics and proper design, sizing, and selection for different Canadian home types and installation scenarios. This type of training supports contractor awareness and familiarity with CCHPs, whereas the manufacturer-led trainings could provide the particular installation procedures, including specific design and control requirements for their product offerings.

This initiative complements and relies on initiatives to develop solutions to address ductless heat pump installation problems in existing homes (SHR&D3), and the initiative to develop Canada-specific sizing and selection tools for heat pumps (SHDEP4).

Key Stakeholder Roles:

- Lead Organizations: Manufacturer organizations, industry organizations, contractors, manufacturers.
- Supporting Organizations: NRCan, utilities / efficiency organizations, home builder associations.

Key Activities:

- Conduct inventory of contractor training, certification, and education requirements throughout Canada, and conduct targeted interviews with stakeholders to understand needs for a certification program.
- Conduct stakeholder workshop to discuss initial framework for CCHP training and certification program, requirements, outreach strategy, branding lead organizations, etc.
- Develop training program, educational materials, and other resources, and prepare program launch strategy.
- Conduct outreach to partner stakeholders to drive program participation, adopt training and certification requirements as part of CCHP incentive programs, track market awareness and adoption in local markets.

Incentives

SHDEP9 – Expand access to and uptake of existing and future heat pump incentive programs

Focus: Residential and commercial buildings

Electric heat pumps, including CCHP and GSHP, could provide substantial energy savings and non-energy benefits for residential and commercial buildings, but in some regions the high incremental cost can be a significant barrier to adoption. Numerous utilities, and government efficiency organizations across Canada offer incentives for electric heat pumps and other energy efficient space heating technologies; and some have explored alternate financial models like financing. Some regions have had significant market uptake and support from local contractors, and this information could be shared across Canada. Stakeholders should explore ways to expand and improve existing incentive programs and other financial mechanisms, share best practices to other utilities / efficiency organizations, and develop new strategies to encourage adoption of CCHP and GSHP technologies. This should also involve industry organizations and contractors to make sure program design, eligibility criteria, and other parameters are appropriate for their businesses.

Some Canadian utilities and government efficiency organizations offer incentive programs today, which could provide an example to other regions. In addition, as part of the LCEF, the Government of Canada is providing $1.4B to provincial and territorial governments for GHG mitigation measures that include energy efficiency retrofits. Appendix 7.2 provides an overview of existing incentive programs for high efficiency space heating equipment by jurisdiction in Canada.

This initiative could be supported by SHR&D2, which promotes research into hybrid heat pump solutions that could potentially increase heat pump uptake.

Key Stakeholder Roles:

- Lead Organizations: Utilities / efficiency organizations, provincial and territorial governments.
- Supporting Organizations: NRCan, industry organizations.

Key Activities:

- Conduct targeted interviews with program managers at utilities / efficiency organizations, government agencies, and other energy efficiency organizations to gather best practices for current incentive programs.
- Prepare a report, checklist, and other materials that outline best practices for starting, growing, and

maintaining a CCHP incentive program.

- Conduct outreach to promote the best practice guidelines to utilities and government efficiency organizations that do not currently have CCHP incentive programs.
- As necessary, update the best practices report and other materials to track progress, highlight innovative programs, etc.

Codes & standards

SHDEP10 – Influence and support development and harmonization of codes and standards for heat pumps

Focus: Residential and commercial buildings

Heat pumps are an emerging technology in Canada, and many codes and standards organizations, contractors, design engineers, inspectors, and insurers may be cautious based on their limited track record in Canadian climates. For many stakeholders, there is concern about heat pumps operating as the primary space heating system in Canadian climates without backup heating systems. Even if code changes allow heat pumps as primary space heating systems, contractors and other parties may be unsure about the new options, and default to older code requirements particularly when it comes to safety, reliability, occupant satisfaction, and code compliance. Stakeholders should support the updating of building codes and insurance practices, where necessary, to maximize harmonization of energy efficiency requirements for heat pumps across Canada. In addition, Stakeholders should develop outreach and communication programs to help building industry stakeholders across the supply chain gain familiarity with new space heating technologies, and their code compliance for future installations.

The federal government can also help stakeholders throughout the space heating value chain to better understand codes by developing guidelines that describe performance criteria, specification language, code references, and the differences between codes for the retrofit versus new construction market.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, codes and standards organizations.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Engage the code development process to raise awareness of the road map and its aspirational goals for energy performance of space heating.
- Determine if any performance ratings must be updated to support code process with respect to energy efficiency.
- Work with provincial and territorial governments to promote timely code adoption.
- Track requirements across the country to understand playing field of energy efficiency requirements, and use that information to inform further harmonization efforts.

SHDEP11 – Develop high performance specifications for CCHPs

Focus: Residential buildings

Consumers often look for products that carry a specific label or certification when making their purchasing decisions, and this strategy could be useful to designate high efficiency heat pumps that perform well in Canadian climates. Programs like ENERGY STAR®[44] and the Consortium for Energy Efficiency (CEE) tiers provide information to consumers, but also send a competitive signal to manufacturers to develop new technologies that raise the highest level of performance for the industry. Creating tiered or challenge specification programs for CCHPs would support both consumer awareness and manufacturer development of higher performance products. Stakeholders should consider developing a high performance specification for CCHP products that ensures products meet the most demanding Canadian conditions. This initiative could build on the work of Initiative SHDEP3 to develop Canadian performance ratings for CCHPs, and Initiative SHDEP4 to demonstrate CCHPs across Canada.

Programs like the Northwest Energy Efficiency Alliance's (NEEA) Advanced Water Heater Specification[45] and the Northeast Energy Efficiency Partnerships' (NEEP) Cold Climate Air-Source Heat Pump specification[46] provide excellent examples for balancing the needs of consumers, contractors, utility / efficiency organization programs, and manufacturers. Once launched, the high performance specifications could be promoted throughout utility, efficiency organization, and industry programs, and supported through market transformation activities like training, design guides, recognition and award programs, as well as workshops to share best practices, track market adoption, and refine the specification program. This initiative will be informed by demonstrations of CCHPs to support nationwide marketing (SHDEP1).

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Conduct inventory of high performance specifications in other technology areas (e.g., ENERGY STAR Most Efficient, U.S. DOE Rooftop Unit Challenge, NEEA, NEEP, etc.) and targeted interviews with utility, efficiency organization, and government program managers, manufacturers, and industry organizations to gauge interest in a high performance specification for CCHPs.
- Prepare initial framework for high performance specification.
- Launch high performance specification, conduct outreach to partner stakeholders to drive participation, and highlight successful demonstrations, partnerships, products, etc.
- Develop incentive and marketing programs around high performance specification, track market awareness and adoption in each local market, and share best practices across regions.

[44] NRCan. 2018. "ENERGY STAR Most Efficient." March 2018. Available at: http://www.nrcan.gc.ca/energy/products/energystar/why-buy/13612
[45] NEEA Advanced Water Heater Specification webpage. Accessed May 2018. Available at: http://neea.org/advancedwaterheaterspec
[46] NEEP Cold Climate Air Source Heat Pump webpage. Accessed May 2018. Available at: http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump

4.4. Key stakeholder roles for space heating initiatives

Table 4-2 highlights the key stakeholder roles for priority R&D and deployment initiatives for space heating technologies.[47] Each initiative requires coordination amongst governments, manufacturer, industry, and utility stakeholders to achieve the short-, medium-, and long-term goals for improving the energy efficiency of space heating systems throughout Canada. Stakeholders must provide ongoing support and continued cooperation for deployment efforts to maintain momentum in the marketplace. Section 6 further describes strategies for market deployment success.

Table 4-2 Summary of Stakeholder Involvement for Space Heating Activities

Activities	Stakeholder Roles and Responsibilities
R&D for Product Development	• NRCan has a lead role to coordinate, support, and guide R&D projects for space heating technologies. Provincial and territorial governments, some manufacturer associations as well as utilities / efficiency organizations also support R&D activities in some jurisdictions where emerging technology programs exists. • Manufacturers, federal laboratories, research organizations, or other parties often lead the actual research activities, product development, and information dissemination for space heating technologies.
R&D for Laboratory and Field Testing	• Independent testing laboratories and other researchers develop test protocols, monitoring and other characteristics for laboratory and field testing of space heating technologies. • NRCan supports these testing efforts and gain a better understanding of system performance. • Provincial and territorial governments and utilities / efficiency organizations, support these efforts by identifying host sites and promoting findings.
Demonstration	• NRCan and federal laboratories have a role in engaging with various stakeholders to co-fund and initiate projects for space heating technologies. • Manufacturers and industry organizations have a lead role in identifying major installation issues, developing solutions, and working with their networks of contractors and builders to gather “front line” feedback. Provincial and territorial governments and utilities / efficiency organizations also play a large role in funding of these projects, often acting as partners for implementation. • Provincial and territorial governments and utilities / efficiency organizations have a lead role in creating local demand and supporting local contractors, design engineers, energy advisors, inspectors, and other stakeholders.

[47] This table summarizes the major activities and roles detailed in the initiative descriptions. The responsibilities and relationship between lead and supporting organizations will vary by initiative.

Activities	Stakeholder Roles and Responsibilities
Information & Awareness	• Governments have a role in supporting a level playing field for different manufacturers through development of test procedures and performance metrics for space heating technologies. • Governments and utility / efficiency organizations also support national efforts to develop programs by supporting test standards, calling up certification requirements, and support qualified product lists for space heating technologies. • Codes and standards organizations, manufacturers, and industry organizations to develop the test procedure. Manufacturers then certify products. • Ongoing activities, e.g. LEEP, labelling, etc., carried out by multiple stakeholders all serve to increase information and awareness.
Training	• Manufacturers, utilities / efficiency organizations, and industry organizations prepare training and education materials for contractors, engineers, builders, inspectors, insurers, and other stakeholders, and develop and deliver installer certification programs.
Incentives[48]	• Provincial and territorial governments and utilities / efficiency organizations have a greater role in creating local demand for space heating technologies and supporting local contractors, engineers, energy advisors, inspectors, and other stakeholders. • Utilities / efficiency organizations have a strong relationship with customers and have supported the adoption of advanced technologies through current incentive programs. These programs would need to adapt over time to accommodate market and technology changes; industry organizations could support by providing their insights and expertise.
Codes & Standards	• Governments, manufacturers, and industry organizations gather the information necessary to influence and support changes to codes, standards and practices as they relate to space heating. Codes and standards organizations implement changes where necessary. • Governments develop high performance specifications, such as ENERGY STAR®, to support both consumer awareness and manufacturer development of higher performance products. Manufacturers and industry organizations provide technical support to define and/or inform performance levels and program requirements.

Table 4-3 outlines the high priority initiatives identified for space heating technologies and cross references them with each of the attributes associated with the 5A's framework. While each initiative can support several of the 5A's, only the key ones have been identified below. This table is intended to provide additional context regarding the barriers that have been identified above.

[48] Appendix 7.2 provides an overview of existing incentive programs for high efficiency space heating equipment by jurisdiction in Canada.

Table 4-3 Key Barriers Addressed by Space Heating Initiatives

Initiative #	Initiative Name	Availability	Accessibility	Awareness	Affordability	Acceptance
SHR&D1	Research to develop high efficiency, lower cost CCHPs.	●			●	
SHR&D2	Develop hybrid heat pump solutions, controls, and installation guides.	●		●	●	●
SHR&D3	Develop solutions to address ductless heat pump installation issues for existing homes.			●		●
SHR&D4	Research to reduce ground loop installation costs for GSHPs.				●	
SHR&D5	Research to develop lower cost components for gas heat pumps.	●			●	
SHR&D6	Conduct lab and field testing for gas heat pumps in Canadian climates.	●	●			
SHR&D7	Conduct lab and field testing for advanced technologies.	●	●			
SHDEP1	Conduct demonstrations of CCHPs to support nationwide marketing.		●	●		●
SHDEP2	Conduct demonstrations of gas heat pumps to educate consumers and industry.			●		●
SHDEP3	Develop Canadian performance ratings and QPL for CCHPs.			●		
SHDEP4	Develop Canadian sizing and selection software tools.		●	●		
SHDEP5	Develop construction industry market pull for high efficiency space heating systems.		●	●		●
SHDEP6	Develop test procedures and performance ratings for combination electric heat pump systems.			●		
SHDEP7	Develop test procedures and performance ratings for gas heat pumps.			●		
SHDEP8	Develop heat pump training and contractor certification program.			●		●
SHDEP9	Expand access to and uptake of existing and future heat pump incentive programs.			●	●	
SHDEP10	Influence and support development and harmonization of codes and standards for heat pumps.		●	●		
SHDEP11	Develop high performance specifications for CCHPs.	●	●	●		

5. WATER HEATING

This section contains a R&D and deployment road map for residential and commercial water heating equipment and systems.[49] This section covers domestic hot water systems and does not discuss combination space-and-water-heating systems that serve both building end-uses through a single appliance or system; information about combination systems can be found in the space heating section.

5.1. Technology description

Domestic water heating systems provide hot water for faucets, bath and shower fixtures, dishwashers, clothes washers, and other applications within residential and commercial buildings. Water heating is the second largest source of energy consumed in homes, and accounts for 19% and 8% of total energy consumed in residential and commercial buildings, respectively.[50] Most buildings have one or more centrally located water heaters that supply hot water throughout the building using a pipe network, but some buildings with lower usage have distributed "point-of-use" water heating systems.

Current Canadian buildings primarily use natural gas and propane for water heating (72%), with electricity (21%), fuel oil (5%), and other heating fuels such as biomass (2%) accounting for a smaller share of the market. Today, 75% of residential gas-fired instantaneous water heaters sold are condensing technology (>90% efficiency), but only 1% of residential gas storage and 30% of commercial gas storage water heaters sold reach these efficiency levels. Electric heat pump water heaters (HPWHs) increase efficiency well beyond 100% (relative to electric resistance technology), but currently account for less than 1% of residential and commercial electric storage water heater market.[51] Water heaters are generally classified by their system design and fuel type:

- System type: storage tank, instantaneous; and
- Fuel source: natural gas, propane, oil, electricity, solar.

Energy performance of water heating is measured differently based on the type of equipment. A summary of the metrics used to measure water heating performance is contained in

[49] This road map focuses on improving the energy efficiency of water heating equipment and systems to reduce site energy consumption, and does not evaluate source energy consumption and emissions, which vary by location across Canada.
[50] NRCan. 2014. National Energy End-Use Database.
[51] NRCan. 2017. "Market transformation strategies for energy-using equipment in the building sector." August 2017. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf

Figure 5-1.

Figure 5-1 Water Heating Energy Performance Measurements

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)[52] – 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 rate of 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. Heat pumps extract heat present in air, water or earth and transfer it to heat water. As the technology uses heat already present in the natural environment or a conditioned space, it performs at levels beyond 100% (i.e. one unit of energy to run the heat pump created more than one unit of heat).*

Condensing storage water heaters, electric HPWHs, and gas HPWHs (e.g. absorption, engine driven and thermal compression technologies), and other advanced technologies will be important contributors to achieving Governments' aspirational goals for water heating. Nevertheless, these technologies require R&D and deployment actions to address the unique barriers to successful market adoption.

Figure 5-2 highlights the Canadian Governments' short-, medium-, and long-term aspirational goals for energy performance of water heating. The aspirational goals cover residential and commercial technologies that use natural gas and electricity; and include R&D targets that support the development of next generation technologies.[53] They recognize the range of heating systems and fuel types used today and the challenges within the existing building market; and the fact that different regions of the country have unique geography, different energy costs, emission intensity of the grid and available fuel sources. For these reasons, they include multiple pathways to meet the energy performance targets.

These aspirational goals outline a transition, to heat pump technologies for electrical systems, and a transition to condensing and heat pump technologies (e.g. absorption, engine driven and thermal compression gas heat pumps) for fuel-fired systems.

[52] NRCan is transitioning to a Uniform Energy Factor starting 2019 for some water heaters.

[53] 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 road map.

Figure 5-2 Aspirational Goals to 2035 for Water Heating in Canadaa

***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. (R&D target).*[54]

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

5.2. Key technical and market challenges

Table 5-1 outlines key barriers for water heating technologies, broken into technical barriers, and market barriers, respectively.

Table 5-1 Technical and Market Challenges and Barriers

Challenge / Barrier		Description
Technical	**Performance in Canadian Climates**	Electric and gas HPWHs operate by capturing heat from indoor or outdoor air. System performance in colder Canadian climates could reduce energy savings because the heating capacity of heat pumps drops as outdoor temperatures decrease. Increased energy consumption is necessary to achieve the higher temperature lift when drawing thermal energy from the outdoor air or when drawing thermal energy from indoor air to heat water affects space heating loads.
	Test Procedures and Performance Ratings	Gas HPWHs and electric combination space and water heating systems require additional test procedures and ratings development. There is also no standardized approach to specify minimum water heater temperature set points to address Legionella issues.
	Retrofit Challenges	Electric HPWHs pose size, weight, airflow, noise and other installation issues for existing buildings that may require customized installation practices.
	Remote and Northern Communities	Remote and northern communities have challenging water heating requirements based on fuel availability and other unique circumstances. The high efficiency options discussed in the road map may have limitations in these regions that will need to be addressed.

[54] The R&D 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 road map.

	Challenge / Barrier	Description
	Operations / Maintenance	Maintenance requirements and durability of electric and gas HPWHs are not well understood. Electric and gas HPWHs may also carry longer recovery times than conventional storage water heaters, which may impact their ability to meet high loads in commercial applications.
Market	**Product Availability**	Contractors and distributors often do not stock high efficiency electric HPWHs (i.e. condensing technology), which poses accessibility issues as most water heater purchases are urgent replacements. Gas HPWHs are not fully commercialized in Canada.
	Higher Upfront Cost	High efficiency technology carries higher upfront costs, which could be a disincentive to adoption, especially for homeowners with a limited budget and building owners who do not pay utility bills. Low gas and electricity rates could also lead to unreasonably long payback periods. Decreased water usage may also increase the payback duration for high efficiency gas and electric HPWHs.
	Awareness of Technologies	Engineering service providers, design engineers, contractors, and building owners have limited experience and knowledge of the design, installation, commissioning, maintenance and other aspects of advanced water heating systems. Complexity of installation diminishes the attractiveness of the product to contractors.

Figure 5-3 summarizes the current technology and market status for water heating technologies in "5A's framework".

Figure 5-3 5A's for Water Heating Technologies

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 HPWHs	Yes	To some extent	To some extent	No	No
Gas HPWHs	To some extent	No	No	No	No

Yes No To some extent

5.3. Road map for water heating technologies

The following figures show the high priority R&D and deployment initiatives identified through the road mapping process for electric HPWHs, gas HPWHs and other advanced technologies (e.g. solar thermal) to address the technical and market barriers identified. Initiatives ranked as lower priority are not included in the road map, but their descriptions can be found in Appendix 7.5.

Residential condensing storage water heaters are available on the market today, but have not achieved market success similar to condensing instantaneous models.[55] Governments recognize there are continued barriers to the deployment of condensing technology to residential-sized gas-fired storage tanks and will continue to look at the right regulatory approach for this product, including discussion with manufacturers regarding approaches for cost reduction and potential collaboration with utilities regarding incentive program opportunities. For these reasons, they are not directly addressed in the road map initiatives below.

[55] NRCan estimates 75% of residential gas-fired instantaneous water heaters sales have >90% energy efficiency. NRCan. 2017. "Market transformation strategies for energy-using equipment in the building sector." August 2017. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Market-Transformation-Strategies_en.pdf

Figure 5-4 Timeline of R&D Initiatives for Water Heating

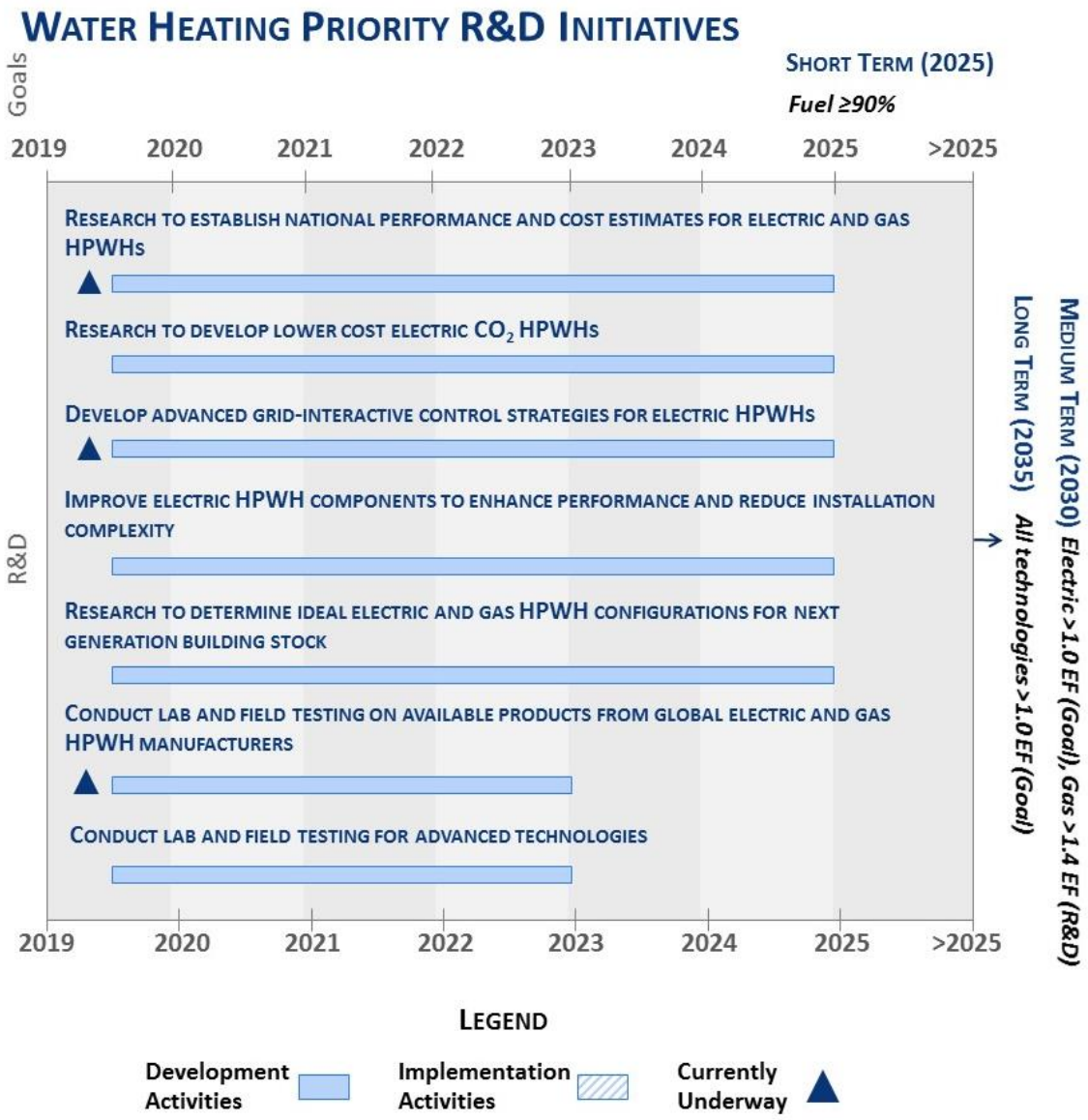
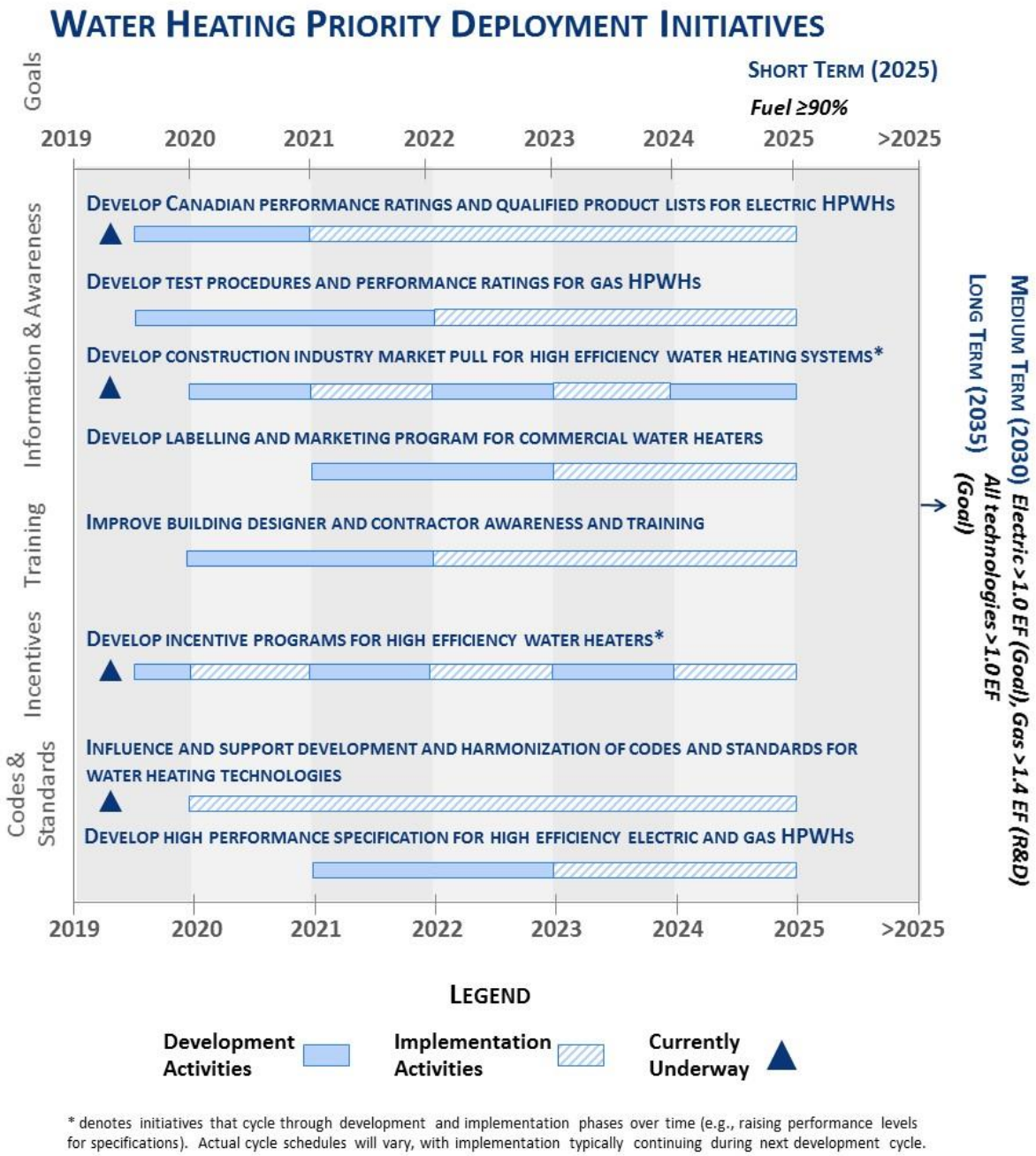


Figure 5-5 Timeline of Deployment Initiatives for Water Heating



* denotes initiatives that cycle through development and implementation phases over time (e.g., raising performance levels for specifications). Actual cycle schedules will vary, with implementation typically continuing during next development cycle.

5.3.1 R&D initiatives for water heating technologies

The following section provides detail on the high priority R&D initiatives for water heating technologies. These R&D initiatives could be used to inform NRCan's funding decisions starting as early as 2019-2020. These technologies could be included in the scope of priority areas in future calls for project proposals under the Energy Innovation Program. In carrying out R&D initiatives, NRCan would seek partnerships with stakeholders (in particular Canadian manufacturers) and would consider funding external organizations to undertake independent research.

WHR&D1 – Research to establish national performance and cost estimates for electric and gas HPWHs

Focus: Residential and commercial buildings

Limited information is available to Canadian consumers to make decisions on the best water heater technology to fit their needs and achieve utility cost savings. Stakeholders should conduct an expansive analysis to establish energy savings, performance, payback, and other data for electric and gas HPWHs in different Canadian markets. This research would build on existing CanmetENERGY building simulation research into electric and gas HPWH performance for Canadian homes across different regions.[56] This follow-on research should consider a variety of Canadian conditions (i.e., utility rates including time-of-use electricity rates, water characteristics, number of occupants, typical usage patterns, types of plumbing fixtures, etc.) with a goal of developing marketing and education strategies using the data. In particular, these activities could focus on water heater rental programs, which are common in certain regions. One example for marketing materials could be a consumer-facing website and adjustable calculator that could easily communicate energy consumption, payback, GHG emissions savings, and other parameters, so that contractors, design engineers, and consumers could tailor the results to their individual project.

Key Stakeholder Roles:

- Lead Organization: NRCan, federal laboratories.
- Supporting Organizations: Industry organizations[57], provincial and territorial governments, utilities / efficiency organizations.

WHR&D2 – Research to develop lower cost electric CO_2 HPWHs

Focus: Residential buildings

Despite their availability and success in other global markets, electric CO_2 HPWHs are just emerging onto the North American market. Today's products carry a substantial cost premium, which limits their market adoption despite high efficiency performance. Electric CO_2 HPWHs could play an important role as a low GWP refrigerant option in the near future, and stakeholders should conduct research to

[56] Kegel et al. 2017. "Heat Pump Water Heaters in the Canadian Residential Market." NRCan CanmetENERGY. 12th IEA Heat Pump Conference 2017. Available at: http://hpc2017.org/wp-content/uploads/2017/05/P.1.7.6-Heat-Pump-Water-Heaters-in-the-Canadian-Residential-Market.pdf

[57] The generic term "industry organization" is used to mean the following: home builders associations, manufacturer associations, inspector, contractors, and installer associations, utility associations, and other organizations that represent a specific trade or membership involved in the building sector.

support the development of lower cost systems for North American markets. Electric CO_2 HPWHs may be particularly cost-effective when operating as a combined space and water heating system. NRCan has identified the need to evaluate the technology further as part of its electric HPWH research and some small demonstration projects have been completed (e.g. lessons learned from British Columbia).[58] Current electric CO_2 HPWHs have higher cost and complexity due to the need for complex refrigerant-to-water heat exchangers, variable speed compressors, advanced controls, electronic expansion valves, etc.[59] This research should develop upfront cost and performance targets that would lead to acceptable paybacks in a variety of home designs and utility regions, and also identify opportunities to reduce installation cost and complexity.

This initiative would benefit from coordination with the U.S. and international partners. Organizations such as U.S. DOE[60], leading U.S. and Japanese manufacturers of HPWHs, and international research organizations such as the IEA HPT TCP could work together to develop the next generation of high efficiency, low cost CO_2 HPWHs.[61]

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Provincial and territorial governments, manufacturer organizations, utilities / efficiency organizations.

WHR&D3 – Develop advanced grid-interactive control strategies for electric HPWHs

Focus: Residential buildings

Electric water heaters could provide additional capabilities to the Canadian electrical grid, such as providing demand response during peak events, balancing renewable electricity, improving localized power quality, and optimizing consumption patterns. Stakeholders should develop control technologies and utility / efficiency organization programs to incentivize grid-interactive control capabilities for electric HPWHs for demand response, time-of-use-rates, etc. These control systems should meet safety requirements and reliability expectations of consumers and ensure that it does not increase risks for Legionella growth. This research could also identify non-energy benefits such as remote connectivity, fault detection, etc. and quantify the potential benefits for demand response programs.

Key Stakeholder Roles:

- Lead Organizations: NRCan, utilities / efficiency organizations, provincial and territorial governments.
- Supporting Organizations: Manufacturers, federal laboratories, research organizations.

[58] Kegel et al. 2017. "Heat Pump Water Heaters in the Canadian Residential Market." NRCan CanmetENERGY. 12th IEA Heat Pump Conference 2017. Available at: http://hpc2017.org/wp-content/uploads/2017/05/P.1.7.6-Heat-Pump-Water-Heaters-in-the-Canadian-Residential-Market.pdf

[59] Gluesenkamp, Kyle. 2016. "CO2 Heat Pump Water Heater." 2016 U.S. DOE BTO Peer Review. April 2016. Available at: https://www.energy.gov/sites/prod/files/2016/04/f30/32218a_Gluesenkamp_040616-1205.pdf

[60] U.S. DOE BTO Emerging Technologies – HVAC, Water Heating, and Appliances. Accessed May 2018. Available at: https://www.energy.gov/eere/buildings/hvac-water-heating-and-appliances

[61] IEA Heat Pumping Technologies. Accessed May 2018. Available at: http://heatpumpingtechnologies.org

WHR&D4 – Improve electric HPWH components to enhance performance and reduce installation complexity

Focus: Residential buildings

The current generation of electric HPWHs can provide high performance, but future HPWH models, including those with CO_2 and other low GWP refrigerants, could improve their efficiency and customer satisfaction through a number of component improvements. For example, more efficient fans, motors, compressors, and defrost capabilities would reduce auxiliary energy consumption and reduce noise, which is a concern for existing homes. In addition, these component improvements could also reduce the installation complexity of size, weight, airflow requirements, etc. Stakeholders should conduct research to identify ways to improve the performance of specific electric HPWH components to reduce auxiliary energy consumption and installation complexity, and improve customer satisfaction.

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, manufacturers.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations.

WHR&D5 – Research to determine ideal electric HPWH configurations for next generation building stock

Focus: Residential buildings

Canada's building stock becomes more efficient every year as new homes built to today's codes enter the market, and existing homes upgrade their insulation and air tightness levels. Electric HPWHs today often have an indoor evaporator that uses ambient air within the home. More efficient configurations have dedicated air ducts to the outside to avoid increasing the load on the space heating system, but they lead to increased installation cost and complexity. Other electric HPWH products use a split-system configuration with an outdoor evaporator, but may have higher costs. For tomorrow's homes with very low ambient heating loads and high efficiency heating equipment, ducting electric HPWHs to outside may not be necessary, which would reduce installation costs and improve performance for electric HPWH installations. Stakeholders should conduct research to model electric HPWH installations in high efficiency homes to determine an ideal balance of installation cost and high efficiency when placing the electric HPWH evaporator inside or outside the home. Research should consider other ideal solutions, such as combination space and water heating systems (SHDEP6).

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories.
- Supporting Organizations: Contractors, manufacturers, builders, utilities / efficiency organizations, codes and standards organizations.

WHR&D6 – Conduct lab and field testing on available products from global electric and gas HPWH manufacturers to determine performance in cold climate conditions

Focus: Residential and commercial buildings

A number of manufacturers in other global markets offer electric and gas HPWH systems that may be adaptable to Canadian climate and markets. Stakeholders should conduct laboratory and field testing with electric and gas HPWH products available outside of North America, but meet North American

refrigerant standards, to determine their suitability for Canadian climate and customer expectations. In addition, this research should determine the suitability of these products for use as a combination space and water heating system and quantify the performance and efficiency at different ambient temperature conditions. This research would build on NRCan's previous analytical and laboratory research into electric HPWHs for Canadian homes[62], and leverage CanmetENERGY-Varennes anticipated water heating testing capabilities in federal laboratories.[63] The results of laboratory and field testing will inform future demonstration projects.

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, utilities / efficiency organizations.
- Supporting Organizations: Manufacturers, provincial and territorial governments.

WHR&D7 – CONDUCT LAB AND FIELD TESTING FOR ADVANCED TECHNOLOGIES
FOCUS: RESIDENTIAL AND COMMERCIAL BUILDINGS

Advanced technologies (e.g., solar photovoltaics (PV), mCHP) combined with conventional water heating systems (e.g., gas or electric storage water heaters, including HPWHs) could increase the energy savings for consumers, but limited information exists on system performance in Canadian climates and markets. NRCan has supported the development of mCHP[64] and solar thermal systems[65] in recent years, and is currently exploring new technologies in these research areas, including a residential mCHP demonstration in Alberta.[66] Stakeholders should conduct a series of laboratory and field tests to evaluate the performance and efficiency of these combined systems and understand their prospects for further R&D and market support. The results of field testing will determine if broader demonstration projects are necessary.

Key Stakeholder Roles:

- Lead Organizations: NRCan, federal laboratories, research organizations, utilities / efficiency organizations, manufacturers.
- Supporting Organizations: Provincial and territorial governments, manufacturers.

5.3.2 Deployment initiatives for water heating technologies

The following section provides detail on the high priority deployment initiatives for water heating technologies. These initiatives could address important market barriers and challenges to increase uptake of high efficiency water heating technologies into Canadian homes and buildings.

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[62] Kegel et al. 2017. "Heat Pump Water Heaters in the Canadian Residential Market." NRCan CanmetENERGY. 12th IEA Heat Pump Conference 2017. Available at: http://hpc2017.org/wp-content/uploads/2017/05/P.1.7.6-Heat-Pump-Water-Heaters-in-the-Canadian-Residential-Market.pdf

[63] Sunye et al. 2017. "Annex 46 - Heat Pumps for DHW Second Working Meeting." NRCan – CanmetENERGY. September 2016. Available at: http://www.hpt-annex46.org/wp-content/uploads/2017/05/2016-02-Roberto-Suny%C3%A9-Canada.pdf

[64] NRCan. 2018. "Thermoacoustic Cogeneration Engine Development." February 2018. Available at: https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16078

[65] NRCan. 2017. "Plug & Play Building-Integrated Photovoltaic and Thermal (BIPV-T) Technologies." May 2017. Available at: https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16076

[66] Bioenergy International. 2018. "SAIT awarded funding to demonstrate residential micro-CHP retrofit in Alberta." January 2018. Available at: https://bioenergyinternational.com/heat-power/sait-awarded-funding-demonstrate-residential-micro-chp-retrofit-alberta

Information & awareness

WHDEP1 – Develop Canadian performance ratings and QPL for electric HPWHs

Focus: Residential buildings

The efficiency of electric HPWHs depends on the ambient air temperature acting as the heat source, with performance degrading at low temperature conditions. NEEA has developed a cold climate test procedure and Advanced Water Heater Specification to highlight performance in lower temperature environments.[67] Stakeholders should develop or adapt a Canadian test procedure and performance ratings for electric HPWHs that could account for cold climate conditions. This initiative would be similar to CSA EXP07, which was developed for air-source heat pumps for space heating. These performance ratings will help establish a list of qualified equipment so utilities can move towards adopting the test procedures, ratings, and equipment list as part of their energy efficiency programs that reward higher incentives for cold climate performance characteristics. This effort could also explore standardized approaches to specify minimum water heater temperature set points to address Legionella concerns.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, codes and standards organizations.
- Supporting Organizations: Industry organizations, manufacturers.

Key Activities:

- Develop or adapt an electric HPWH test procedure and performance ratings that could account for cold climate conditions.
- Publish final test procedure, develop certification protocols including the need for lab testing and begin certifying electric HPWHs to the test procedure.
- Prepare publicly available list of qualified electric HPWHs and establish performance criteria for utility / efficiency organization programs using the qualified product lists.
- Revisit utility / efficiency organization incentive programs once the QPL is available to ensure alignment.

WHDEP2 – Develop test procedures and performance ratings for gas HPWHs

Focus: Residential and commercial buildings

Gas HPWHs do not currently have test procedures and energy efficiency performance. The energy efficiency of gas HPWHs has multiple variables. Products have an efficiency curve at different capacities and indoor/outdoor temperatures, and then energy consumption values for natural gas and electricity for auxiliary components (e.g., pumps, fans, etc.). Stakeholders should test these products to understand the requirements for a test procedure, and then develop performance ratings to help characterize the performance of gas HPWHs. This activity would help stakeholders evaluate the performance of different products, and project energy consumption and utility costs in their region.

[67] NEEA Advanced Water Heater Specification webpage. Accessed May 2018. Available at: http://neea.org/advancedwaterheaterspec

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, codes and standards organizations.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Conduct inventory of current test methods for gas storage water heaters, electric HPWHs, and related water heating products.
- Define scope and key requirements of a gas HPWH test procedure(s).
- Develop initial test procedure(s), and conduct laboratory research to evaluate the test procedure(s).
- Begin certifying gas heat pumps to the test procedure(s).

WHDEP3 – Develop construction industry market pull for high efficiency water heating systems

Focus: Residential buildings

Manufacturers wanting to deploy new energy efficient technologies in the construction sector have to overcome the additional barrier of entering a market that is local, and fragmented with many builders and renovators that lack the time and resources to consider the impact of new technologies on their business practice. Builders and renovators know their current approach and are hesitant to try new technologies since they are perceived as adding scheduling, cost, and call-back risks.

NRCan's LEEP program helps regional builder and renovator groups find, select and evaluate the new energy efficient technology solutions that best meet their needs. For manufacturers, LEEP provides opportunities to learn how market leaders see the comparative benefits of different technologies; work with a group of builders that have already become knowledgeable about their technology and have a specific application in mind; learn how their technology offering could be adapted to better meet local market needs; and, access a critical mass of builders that could make it cost effective to support a new product in a particular region. Stakeholders should develop regional LEEP initiatives with provincial governments, utilities / efficiency organizations, and home builder associations.

Key Stakeholder Roles:

- Lead Organization: NRCan.
- Supporting Organizations: Provincial and territorial governments, utilities / efficiency organizations, home builder associations, contractors, manufacturers.

Key Activities:

- Build partnerships and initiate local initiatives with provincial governments, utilities / efficiency organizations, and home builder associations.
- Work with leading local builders to select the technologies they want to focus on, define the applications they are most interested in, and select the manufacturers they would like to present solutions.
- Host and deliver technology forums with presenting manufacturers, builders, renovators, trades, energy advisors, and local consultants.

- Deliver and document field trials in which builders evaluate their selected technologies in high performance homes.
- Document and share selection process and field trial results, and develop guides that address gaps identified through those field trials.

WHDEP4 – Develop labelling and marketing program for commercial water heaters to increase awareness of high efficiency options

Focus: commercial buildings

High efficiency water heaters account for a very small percentage of commercial installations in Canada, in part due to high upfront cost and limited awareness of different technologies by building designers, engineers, contractors, and consumers. Labelling programs could have a major impact during the decision-making process, but must provide clear comparison across different fuel types (e.g., gas, electric), system designs, and other attributes. Stakeholders should develop labelling and marketing programs to promote high efficiency commercial water heaters to various decision makers.

This program could communicate the efficiencies of different water heating technologies, and provide a basis for awareness and training to building designers, engineers, contractors, and consumers. Key to the success of this initiative would be to work with commercial water heater manufacturers to ensure the labelling and certification goals align with their marketing, training, and educational materials.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, utilities / efficiency organizations, industry organizations.
- Supporting Organizations: Manufacturers.

Key Activities:

- Conduct inventory of available commercial water heating products, performance specifications, and marketing materials in Canada and conduct outreach to commercial water heater manufacturers, building designer, building owner / operator, and utilities / efficiency organizations to discuss opportunities for a labelling and marketing program.
- Develop and launch labelling program, marketing strategy, and other materials, and incorporate into utility / efficiency organization program, marketing, and other activities.

Training

WHDEP5 – Improve building designer and contractor awareness and training for advanced water heating systems

Focus: Residential and commercial buildings

High efficiency water heating systems such as electric and gas HPWHs and condensing storage models are relatively new to the market, and awareness amongst Canadian builders, engineers, contractors, energy advisors, and other stakeholders is low. Because consumers rely on these industry professionals for recommendations of new technology and systems, increased awareness and training is necessary to drive adoption of high efficiency technologies. Building designers, contractors, and other professionals require additional education on sizing, selection, installation, and servicing procedures for these technologies. Stakeholders should develop education and training programs to

increase familiarity of these technologies amongst building professionals and contractors, so they feel comfortable installing the systems properly and discussing the technologies with consumers. These efforts will need to respect existing trade training requirements in each province and territory, and may complement existing programs. This initiative could be supported by WHR&D1, which would help inform contractors on national estimates for electric and gas HPWHs.

Key Stakeholder Roles:

- Lead Organizations: Manufacturer organizations, contractors, manufacturers.
- Supporting Organizations: NRCan, utilities / efficiency organizations, home builder associations.

Key Activities:

- Conduct inventory of key industry organizations, trade journals, conferences, training events, and other activities where building designers, engineers, contractors, and energy advisors interact and learn about industry developments.
- Conduct outreach to stakeholder groups to discuss opportunities to describe new technologies and develop education / training materials.
- Execute communication and education plan, and maintain communication program to update progress of new technologies, share best practices, etc.

Incentives

WHDEP6 – Develop incentive programs for high efficiency water heaters

Focus: Residential and commercial buildings

High efficiency water heaters could provide substantial energy savings for residential and commercial buildings, but carry a high incremental cost over baseline models, which prohibits their wider adoption. Beyond cost, most water heater sales are for emergency replacements, and the contractor often specifies what can be purchased and installed quickly. Stakeholders should develop incentive programs that target both contractors (midstream) and consumers (downstream) to achieve greater adoption. If contractors and distributors are incentivized to stock products for urgent replacements, one of the key barriers to adoption (i.e., accessibility) can be avoided. Nevertheless, midstream and upstream incentive programs must incentivize downstream demand to be successful. One possibility is midstream incentives for contractors and distributors that include significant downstream marketing to reach consumers.

Some Canadian utilities and government efficiency organizations offer incentive programs today, which could provide an example to other regions. In addition, as part of the LCEF, the Government of Canada is providing $1.4B to provincial and territorial governments for GHG mitigation measures that include energy efficiency retrofits. Appendix 7.2 provides an overview of existing incentive programs for high efficiency water heating equipment by jurisdiction in Canada.

Key Stakeholder Roles:

- Lead Organizations: Utilities / efficiency organizations, provincial and territorial governments.
- Supporting Organizations: NRCan, industry organizations.

Key Activities:

- Conduct targeted interviews with program managers at utilities / efficiency organizations, government agencies, and other energy efficiency organizations to gather best practices for current incentive programs.
- Prepare a report, checklist, and other materials that outline best practices for starting, growing, and maintaining a CCHP incentive program.
- Conduct outreach to promote the best practice guidelines to utilities and government efficiency organizations who do not currently have CCHP incentive programs.
- As necessary, update the best practices report and other materials to track progress, highlight innovative programs, etc.

Codes & standards

WHDEP7 – Influence and support development and harmonization of codes and standards for water heating technologies

Focus: Residential and commercial buildings

New technologies often face acceptance issues beyond technical and economic performance due to restrictions in local building codes, insurance practices, and other necessary processes for buildings. In many cases, the regulations that building inspectors and insurance agencies follow need to be updated in order to allow new water heating technologies to be installed in homes and buildings. These stakeholders are cautious to protect the safety of building occupants and want to avoid burst pipes or health effects from unreliable water heating systems. Stakeholders should support the updating and development of new building codes, as necessary, to maximize harmonization of energy efficiency requirements for water heaters across Canada. In addition, stakeholders could develop outreach and communication programs to help building industry stakeholders across the supply chain gain familiarity with new water heating technologies, and their code compliance for future installations.

The federal government can also help stakeholders throughout the water heating value chain to better understand codes by developing guidelines that describe performance criteria, specification language, code references, and the differences between codes for the retrofit versus new construction market.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments, codes and standards organizations.
- Supporting Organizations: Manufacturers, industry organizations, municipal inspectors.

Key Activities:

- Engage the code development process to raise awareness of the road map and its aspirational goals for energy performance of water heating.
- Determine if any performance ratings must be updated to support code process with respect to energy efficiency.
- Work with provincial and territorial governments to promote timely code adoption.
- Track requirements across the country to understand playing field of energy efficiency requirements, and use that information to inform further harmonization efforts.

WHDEP8 – DEVELOP HIGH PERFORMANCE SPECIFICATION FOR HIGH EFFICIENCY ELECTRIC AND GAS HPWHS

FOCUS: RESIDENTIAL AND COMMERCIAL BUILDINGS

Consumers often look for products that carry a specific label or certification when making their purchasing decisions, and this strategy could be useful to designate high efficiency heat pumps that perform well in Canadian climates. Programs like ENERGY STAR®[68], CEE, and NEEA's Advanced Water Heater Specification[69] provide information to consumers, but also send a competitive signal to manufacturers to develop new technologies that raise the highest level of performance for the industry. Creating tiered or challenge specification programs for electric and gas HPWHs would support both consumer awareness and manufacturer development of higher performance products. Stakeholders should consider developing a high performance specification for advanced electric and gas HPWH products that ensures products meet the most demanding Canadian conditions. This initiative could build on the work of WHDEP1 to develop Canadian performance ratings for electric HPWHs.

Once launched, the high performance specifications could be promoted throughout industry, utility, and efficiency organization programs, and supported through market transformation activities like training, design guides, recognition and award programs, as well as workshops to share best practices, track market adoption and refine the specification program.

Key Stakeholder Roles:

- Lead Organizations: NRCan, provincial and territorial governments.
- Supporting Organizations: Manufacturers, industry organizations.

Key Activities:

- Conduct inventory of high performance specifications in other technology areas (e.g., CEE, NEEA Advanced Water Heater Specification for electric HPWHs) and targeted interviews with utility efficiency organization, and government program managers, manufacturers, and industry organizations to gauge interest in a high performance specification for water heating.
- Prepare initial framework for high performance specification.
- Launch high performance specification, conduct outreach to partner stakeholders to drive participation, and highlight successful demonstrations, partnerships, products, etc.
- Develop incentive and marketing programs around high performance specification, track market awareness and adoption in each local market, and share best practices across regions.

[68] NRCan. 2018. "ENERGY STAR Most Efficient." March 2018. Available at: http://www.nrcan.gc.ca/energy/products/energystar/why-buy/13612

[69] NEEA Advanced Water Heater Specification webpage. Accessed May 2018. Available at: http://neea.org/advancedwaterheaterspec

5.4 Key stakeholder roles for water heating initiatives

Table 5-2 highlights the key stakeholder roles for priority R&D and deployment initiatives for water heating technologies.[70] Each initiative requires coordination amongst government, manufacturer, industry, and utility stakeholders to achieve the short-, medium-, and long-term aspirational goals for energy performance of water heating technologies throughout Canada. Stakeholders must provide ongoing support and continued cooperation for deployment efforts to maintain momentum in the marketplace. Section 6 further describes strategies for market deployment success.

Table 5-2 Summary of Stakeholder Involvement for Water Heating Activities

Activities	Stakeholder Roles and Responsibilities
R&D for Product Development	• NRCan has a lead role to coordinate, support, and guide R&D projects for water heating technologies. Provincial and territorial governments, some manufacturer associations as well as utilities / efficiency organizations also support R&D activities in some jurisdictions where emerging technology programs exists. • Manufacturers, federal laboratories, research organizations, or other parties often lead the actual research activities, product development, and information dissemination.
R&D for Laboratory and Field Testing	• Independent testing laboratories and other researchers develop test protocols, monitoring and other characteristics for laboratory and field testing of water heating technologies. • NRCan and provincial and territorial governments could support these testing efforts and gain a better understanding of system performance. • Utilities / efficiency organizations, and builder associations could support these efforts by identifying host sites and promoting findings.
Demonstration	• NRCan and federal laboratories have a lead role in engaging with various stakeholders to co-fund and initiate projects for water heating technologies. • Manufacturers and industry organizations have a lead role in identifying major installation issues, developing solutions, and working with their networks of contractors and builders to gather “front line” feedback. Provincial and territorial governments and utilities / efficiency organizations also play a large role in funding these projects, often acting as partners for implementation. • Provincial and territorial governments and utilities / efficiency organizations have a greater role in creating local demand and supporting local contractors, engineers, energy advisors, inspectors, and other stakeholders.

[70] This table summarizes the major activities and roles detailed in the initiative descriptions. The responsibilities and relationship between lead and supporting organizations will vary by initiative.

Activities	Stakeholder Roles and Responsibilities
Information & Awareness	• Governments have a role in supporting a level playing field for different manufacturers through development of test procedures and performance metrics for water heating technologies. • Governments and utility / efficiency organizations also support national efforts to develop programs by supporting test standards, calling up certification requirements, and support qualified product lists for water heating technologies. • Codes and standards organizations, manufacturers, and industry organizations to develop the test procedure. Manufacturers then certify products. • Ongoing activities, e.g. LEEP, labelling, etc., carried out by multiple stakeholders all serve to increase information and awareness.
Training	• Manufacturers, utilities / efficiency organizations, and industry organizations prepare training and education materials for contractors, engineers, builders, inspectors, insurers, and other stakeholders, and develop and deliver installer certification programs.
Incentives[71]	• Provincial and territorial governments and utilities / efficiency organizations have a greater role in creating local demand for water heating technologies and supporting local contractors, engineers, energy advisors, inspectors, and other stakeholders. • Utilities / efficiency organizations have a strong relationship with customers and have supported the adoption of advanced technologies through current incentive programs. These programs would need to adapt over time to accommodate market and technology changes; industry organizations could support by providing their insights and expertise.
Codes & Standards	• Governments, manufacturers, and industry organizations gather the information necessary to influence and support changes to codes, standards and practices as they relate to water heating. Codes and standards organizations implement changes where necessary. • Governments develop high performance specifications, such as ENERGY STAR®, to support both consumer awareness and manufacturer development of higher performance products. Manufacturers and industry organizations provide technical support to define and/or inform performance levels and program requirements.

Table 5-3 outlines the high priority initiatives identified for water heating technologies and cross references them with each of the attributes associated with the 5A's framework. While each initiative

[71] Appendix 7.2 provides an overview of existing incentive programs for high efficiency water heating equipment by jurisdiction in Canada.

can support several of the 5A's, only the key ones have been identified below. This table is intended to provide additional context regarding the barriers that have been identified above.

Table 5-3 Key Barriers Addressed by Water Heating Initiatives

Initiative #	Initiative Name	Availability	Accessibility	Awareness	Affordability	Acceptance
WHR&D1	Research to establish national performance and cost estimates for electric and gas HPWHs.			●		●
WHR&D2	Research to develop lower cost CO_2 HPWHs.	●			●	
WHR&D3	Develop advanced grid-interactive control strategies for electric HPWHs.			●	●	●
WHR&D4	Improve electric HPWH components to enhance performance and reduce installation complexity.	●			●	
WHR&D5	Research to determine ideal electric and gas HPWH configurations for next generation building stock.					●
WHR&D6	Conduct lab and field testing on available products from global electric and gas HPWH manufacturers to determine performance in cold climate conditions.	●	●	●		
WHR&D7	Conduct lab and field testing for gas HPWHs in Canadian climates.	●	●			
WHR&D8	Conduct lab and field testing for advanced technologies.	●	●			
WHDEP1	Develop Canadian performance ratings and QPL for electric HPWHs.			●		
WHDEP2	Develop test procedures and performance ratings for gas HPWH.			●		
WHDEP3	Develop construction industry market pull for high efficiency water heating systems.		●	●		●
WHDEP4	Develop labelling and marketing program for commercial water heaters to increase awareness of high efficiency options.			●		●
WHDEP5	Improve building designer and contractor awareness and training for advanced water heating systems.			●		●
WHDEP6	Develop incentive programs for high efficiency water heaters.		●	●	●	
WHDEP7	Influence and support development and harmonization of codes and standards for water heating technologies.		●	●		
WHDEP8	Develop high performance specification for high efficiency electric and gas HPWHs.	●	●	●		

6 KEYS TO MARKET DEPLOYMENT SUCCESS

The initiatives described in this road map support Governments' aspirational goals for energy performance of windows, space heating, and water heating, but require coordination and support from stakeholder groups to ensured sustained momentum in the marketplace. Many stakeholders have experience delivering similar initiatives in their own jurisdictions, providing opportunities to learn from those experiences and improve the implementation of this road map. This section describes best practices for market deployment initiatives and strategies to track the progress and success of the road map initiatives in transforming the Canadian market for these product categories.

6.1 Best practices

At the winter 2018 workshop, attendees discussed best practices for deployment initiatives and provided examples of successful and unsuccessful deployment initiatives in the following breakout sessions:

- Financial incentives;[72]
- Education and training;
- Labelling programs;
- Demonstration programs; and
- Codes and standards.

The following sections summarize the discussions from the deployment breakout session.

Financial incentives

- Incentive programs and other financial mechanisms should be designed for long-term market presence to avoid false economies from "boom/bust" programs in the past. The LCEF is a good kickstart, and appropriate off-ramps are needed once the initial funding ends.
- Incentive strategies should evolve over time and either gradually decrease or sunset incentive values, or increase the performance requirements through multiple tiers.
- Developing consistent performance levels for incentive programs across Canadian jurisdictions could simplify the development of the same QPL and provide consistency for manufactures, consumers, and program designers.
- Midstream and upstream incentives are useful if there are complementary strategies to increase downstream demand. One possibility is midstream incentives for distributors and retailers tied with significant downstream marketing.

[72] Appendix 7.2 provides an overview of existing incentive programs for high efficiency equipment by jurisdiction in Canada.

- When designing incentive programs, demographics and market segmentation need to be top of mind. It is important that incentive programs are designed to ensure that low income communities, including renters, also benefit from incentive programs. Further, incentive programs must be communicated effectively via the right channels so that all stakeholders understand the incentive structure, particularly who is delivering the incentive and who is receiving the incentive.

Education and training programs

- Contractor, engineer, and builder training should be part of utility / efficiency organization programs, including requirements to offer incentives, and sign-up bonuses to incentivize contractors and other parties to participate.
- Utility / efficiency organization programs, where permitted, should have education and certification requirements, and penalize those that have poor customer satisfaction (e.g., a three strikes rule for contractors that participate with their programs).
- Because marketing is a key element of delivering deployment initiatives, stakeholders need to ensure that innovative marketing tools are used to excite consumers about energy efficiency. Marketing is often overlooked in implementing deployment initiatives.

Labelling programs

- Labeling programs should provide clear comparisons of similar equipment across different fuel types (e.g., natural gas, electric, biomass), system designs (e.g., radiator, ductless, baseboard), and other common attributes in customer selection process. The labels should also highlight the full range of product energy efficiency, including best-in-class equipment.
- Third-party labelling programs could inform customers about general technology categories (e.g., electric HPWH vs. electric resistance storage), whereas manufacturer literature could describe the features for their specific products. Consistent labels by third-party programs or manufacturer associations are necessary to avoid unnecessary confusion for consumers and increased burden on manufacturers.
- Labelling programs could have a major impact during the decision-making process for homeowners, businesses, do-it-yourself installers, property managers, and other stakeholders.

Demonstration programs

- Demonstrations need to show the business case, installation complexity, and operating and maintenance features for a new technology rather than just technical capabilities. Consider a 3-step approach: Pilot (does the technology work?), Demonstration (build confidence in business case), Deployment (works in a variety of situations).
- Demonstrations are especially valuable for northern and remote areas where word of mouth is a key driver for market adoption, and there are unique climactic and geographic considerations.

- NRCan's LEEP program[73] supports homebuilders in finding, selecting and evaluating the new technologies that best respond to the needs of their projects, and in sharing the results with the broader industry. For manufacturers, LEEP provides insight into how the construction industry sees the comparative benefits of their technology and many other energy efficient technologies entering the construction sector.

Codes and standards

- Codes, standards and installation practices should focus on addressing current barriers identified by industry, regulators and the insurance industry, such as installation requirements, equipment sizing practices, product labelling, etc.
- Designers, builders, engineers, and contractors require support to learn about code changes and adapt their practices to ensure compliance as well as safety, reliability, and occupant satisfaction.
- Performance ratings for utility / efficiency organization incentive programs should be flexible to allow contractors to match the right high efficiency solution to the building requirements.

6.2 Funding and stakeholder roles and responsibilities

The road map initiatives for each technology covers a wide range of activities, with stakeholders playing different roles for each. Funding for specific road map initiatives would come from a variety of sources, including governments, utility / efficiency organization programs, manufacturers, and industry organizations. Funding discussions for specific initiatives is beyond the scope of the road map. Table 6-1 summarizes the key roles that different stakeholder groups have for the activities discussed in sections 3, 4 and 1.

[73] NRCan LEEP program February 2018. Available at: http://www.nrcan.gc.ca/energy/efficiency/housing/leep/works/17342

Table 6-1 Stakeholders Roles for Key Activities in Each Road Map

Stakeholder	Key Activities						
	R&D for Product Develop-ment	R&D for Laboratory and Field Testing	Demon-stration	Information & Awareness[74]	Training	Incentives	Codes & Standards[75]
NRCan	●	●	●	●	•	•	●
Provincial and Territorial Governments	•	•	●	●		●	●
Federal Laboratories	●	●					
Research Organizations	●	●					
Utilities / Efficiency Organizations	•	●	●	●	•	●	
Manufacturers	●	•	•	•	●		•
Builders / Contractors			•	•	•		
Industry Organizations[76]	•		•	●	●	•	•
Codes / Standards Organizations				●			●

● denotes leading role and • denotes supporting role for key activities.

6.3 Tracking progress

As Governments and stakeholders implement the road map initiatives, they must track the progress of each initiative in overcoming the major technical and market barriers, and increasing market adoption for high efficiency technologies.

[74] This includes test procedures, LEEP, labelling and other information tools.
[75] For the purpose of these road map and the roles and responsibilities identified, standards are referring to voluntary standards such as ENERGY STAR® and mandatory building codes.
[76] The generic term "industry organization" is used to mean the following: home builders associations, manufacturer associations, inspectors, installer associations, utility associations, and other organizations that represent a specific trade or membership involved in the building sector. Certain industry organizations have their own row within this table and should be considered separately. Those not specifically mentioned are included in the industry organizations category.

Table 6-2 outlines possible performance indicators to track the success of these initiatives against the "5A's framework" identified in each road map section. This table includes both quantitative and qualitative metrics, with primary data collection activities outlined in **bold**.

Data collection and tracking progress is a cross-cutting activity that is necessary to determine the ultimate success of the road map initiatives. While each technology and market would have different metrics, data collection, and other attributes, these indicators could help Governments and stakeholders understand whether the market is changing and adapt the R&D and deployment initiatives as necessary to align with market needs. This process could help stakeholders identify when individual windows, space heating, and water heating technologies move from "red" to "yellow" to "green" within the 5A's framework of each road map (Figure 3-3, Figure 4-3, and Figure 5-3).

Table 6-2 Possible Performance Indicators for Market Transformation

Barrier	Possible Performance Indicators
Availability (Does the technology exist?)	• **Number of shipments for high efficiency products or market penetration (percent of high efficiency to total shipments).** • Number of manufacturers and/or available products on the market. • Number of products certified for sale and installation acceptable to building, insurance, safety and other codes. • Products available on the market can easily replace conventional equipment configurations, particularly in retrofit applications.
Accessibility (Does the market have access to the technology?)	• **Available test procedure and performance metrics.** • **Number of models by size/capacity category.** • Number of distributors selling and/or stocking products, and coverage of distributors. • Number of qualified installers and coverage of installers.
Awareness (Does the market know about the technology?)	• Number of utility and government programs promoting the products and coverage area. • Number of educational and training events conducted by industry organizations, and/or participating contractors. • **Focus groups, surveys, and other market research on contractor, engineer, and consumer awareness and attitudes towards technologies.** • **QPLs maintained by leading stakeholder organizations.**

Barrier	Possible Performance Indicators
Affordability (Is the technology affordable?)	• **Incremental cost for product and/or installation over baseline efficiency products.** • Number of financial incentive programs and coverage area. • Average payback period for consumers including operation, maintenance, and other annual costs in different regions.
Acceptance (Is the form, fit, and function of the technology acceptable?)	• **Focus groups, surveys, and other market research on contractor and consumer awareness and attitudes towards technologies.** • Number of warranty claims and/or call backs from contractors. • Number of complaints through online product reviews and social media.

Note: **bold** denotes primary data collection activities. Individual metrics could indicate performance for multiple barriers.

6.4 Governance

Governments plan to work with stakeholders to review market status and progress against the "5A's framework", coordinate ongoing and future initiatives, recognize innovative and successful initiatives, and share best practices across Canadian regions. A series of small implementation teams focused on specific technologies (e.g., windows, electric HPWHs) and sectors (e.g., utility and government efficiency organizations) will be established and launched in fall 2018. Governments would co-lead these teams with the applicable stakeholders. The purpose of each teams would be to (1) flesh out key road map initiatives into a workplan; (2) engage the stakeholders that need to be part of each initiative's key activities; (3) ensure work is on track; and (4) assess whether and how the market is moving over time (including data collection). These implementation teams could meet quarterly, with larger gatherings organized with stakeholders as needed. Individual work plans would be developed by spring 2019. This road map will be formally updated in about five years based on input from the implementation teams.

Concurrent to the work of the implementation teams, Governments will also look to leverage their greening operations programs to advance their aspirational goals.[77] Governments will also provide annual updates to Energy and Mines Ministers and Canadian public through a written progress report that will summarize the current status of the initiatives and performance indicators for market transformation.

[77] Government of Canada. "Greening Government." May 11, 2018. Available at: https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government.html

7 APPENDICES

7.1 Acronyms

AFUE	Annual fuel utilization efficiency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CCHP	Cold climate heat pump
CEE	Consortium for Energy Efficiency
CO_2	Carbon dioxide
COP	heating coefficient of performance
CSA	Canadian Standards Association
DOE	Department of Energy (U.S.)
EF	Energy factor
ER	Energy rating
GHG	Greenhouse gas
GSHP	Ground-source heat pump
GWP	Global warming potential
HPT TCP	Technology Collaboration Programme on Heat Pumping Technologies
HPWH	Heat pump water heater
HSPF	Heating season performance factor
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
$L/s \cdot m^2$	Litres per second per square metre
LBNL	Lawrence Berkeley National Laboratory
LCEF	Low Carbon Economy Fund
LEEP	Local Energy Efficiency Partnerships
Low-e	Low emissivity
m^2	Metres squared
mCHP	micro combined heat and power
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnership
NRCan	Natural Resources Canada
PCF	Pan-Canadian Framework on Clean Growth and Climate Change
QPL	Qualified product list / listing
R&D	Research and development
SCOP	Seasonal coefficient of performance
SHDEP#	Space heating deployment initiative
SHR&D#	Space heating R&D initiative
SHGC	Solar heat gain coefficient
Solar PV	Solar photovoltaic
UA	United Association
Ufactor	Heat Loss Coefficient (W/m^2K)
$W/m^2 \cdot K$	watts per square metre degree Kelvin
WHDEP#	Water heating deployment initiative
WHR&D#	Water heating R&D initiative
WINDEP#	Windows deployment initiative
WINR&D#	Windows R&D initiative

7.2 Summary of existing incentive programs for windows, space heating, and water heating

Table 7-1 Available Financial Incentive Program Availability in Canadian Jurisdictions (June 2018)

Technology	Program	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Nova Scotia	P.E.I.	Newfoundland / Labrador	Northwest Territories	Yukon	Nunavut
Windows	ENERGY STAR windows (zone 3 or Most Efficient)	●	●		●			●	●	●			●	
Space Heating	Natural gas heat pumps							●						
	Cold climate air-source heat pumps	●				●	●	●	●	●	●		●	
	Ground-source heat pumps	●			●	●	●	●	●	●	●		●	
	Condensing commercial gas furnaces		●	●		●	●					●		
Water Heating	Natural gas heat pumps	●	●				●	●						
	Electric heat pump water heaters	●						●	●	●				
	Condensing storage water heaters	●				●	●	●		●				

Table 7-2 Available Non-Financial Program Availability in Canadian Jurisdictions (June 2018)

Program	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Nova Scotia	P.E.I.	Newfoundland / Labrador	Northwest Territories	Yukon	Nunavut
Awareness / information (i.e. intended for a general audience)	●			●	●	●	●	●	●	●		●	
Training / technical assistance (i.e. for a professional certification)	●	●	●	●	●		●	●					
Emerging technologies (R&D) (i.e. specific to road map priority technologies)	●	●		●	●	●							

Note: there are other non-incentive programs available in some jurisdictions, for example: sub metering projects, home energy coach hotline, financing programs, etc.

7.3 Workshop summaries

NRCan and Navigant held workshops with windows, space heating, and water heating stakeholders in phase 1 of the road map. For each technology type, a workshop focusing on R&D objectives was held, and a separate workshop focusing on deployment objectives was held.

During the workshops, a large brainstorming session was held with the entire group of stakeholders, followed by smaller break out sessions to discuss specific topics. After these activities, stakeholders generated key initiatives that were then discussed and voted on by stakeholders in order to compile a list of high priority initiatives.[78] These prioritized initiatives are found in the tables below.

Table 7-3 High Priority Window R&D Initiatives

Session	Initiative	Votes
Windows	Study of U-factor vs. SHGC (ER), what are the trade-offs and attributes of each rating.	15
Windows	R&D into thin triple pane windows with low e-coatings, including the durability of such coatings.	13
Windows	Examine impact on performance of different window configurations (i.e., performance of overall window system with combinations of different windows and different window attachments).	10
Windows	Examine whether there can be improved designs to reduce thermal bridging.	8
Windows	Research into window frames to understand edge performance (thermal, durability etc.).	7
Windows	Study into process re-design for the manufacturing of windows helping to drive down the costs of new technology windows.	6
Windows	Research into double window designs coupled with cost and performance.	6
Windows	Research into vacuum glazing technologies.	5
Windows	Research into the process of developing 2 e-coatings on single panes.	3
Windows	Study of high performance windows in terms of U-factor and SHGC ratings.	3
Window Attachments	Research into making dynamic glass more accessible to residential customers, helping to reduce costs and mitigate issues arising from electrical wiring etc.	4
Window Attachments	Research into how window attachments affect the overall window system (degradation of window panes/sills, overheating issues between windows and the window attachments etc.).	3

[78] The voting at least partially reflects the interest and background of the attendees, and for some workshops, the attendees were asked to only vote on the set of initiatives from the breakout sessions that they attended. The voting process helps segment high priority and low priority topics from a group of experts, but the final initiative prioritization for the road map uses a separate set of metrics, described in Section 2.

Table 7-4 High Priority Window Deployment Initiatives

Initiative	Votes
NRCan to provide a simplified source of information regarding the benefits of window products and the available window incentive programs on the market. This source should also include information on window products that arise from different regional geographies.	43
Provide sustainable tax rebates for installations (GST/HST).	27
Mandatory disclosure of energy and GHG performance upon sale of homes.	18
Facilitate installer training/certification window programs.	18
Develop codes for new construction that involve the use of high efficiency windows.	11
NRCan to enable stakeholders to hold demonstration projects that can show economic paybacks for home upgrades, especially for older homes – these demonstration projects should also show the performance and comfort attributes of upgrading windows. Further, education materials need to be developed that can be easily understood (graphics, simple messages etc.).	10
Industry would like to see long term demand forecasts for window technologies to support strategic planning.	7
Need to further test glazing materials to better understand reliability and durability (5 years plus).	7
Provide a tiered incentive program (i.e., incentives based upon level of energy savings).	6
Provide funding to support redesign and certification of product manufacturing (especially for small/medium manufacturers).	5
Develop simple labelling for window products and correspondingly, provide enforcement and accountability for standardized labelling for window products.	5
Help address limited flat glass supply in Canada and North America, especially low-e coating glass (both retrofit and new construction).	4

Table 7-5 High Priority Space Heating and Water Heating R&D Initiatives

Session	Initiative	Votes
Electric Heat Pump	Modeling to consider savings with indoor evaporator – in a very well insulated 2030 home with a highly efficient heating system an indoor evaporator may achieve a better balance of cost and high efficiency than an outdoor one.	6
Electric Heat Pump	Develop best practices and targets for combination space and water heating systems – heat pumps for water heating are more economically feasible when used in combination systems.	5
Electric Heat Pump	Investigate fouling issues in electric HPWHs in hard water regions.	4
Electric Heat Pump	Evaluate long life tank materials – heat pumps have a life of 15 -20 years, while tanks only have a life of 8-12 years – if tank life can match heat pump life, replacement intervals can be synchronized.	4
Electric Heat Pump	Design and evaluate a heat pump product that is “solar PV ready”, and that can be connected and used in PV assisted water heating.	3
Gas Heat Pump	Research into systems modeling for gas heat pumps, considering water and space heating interactions.	9
Gas Heat Pump	Develop test procedures and standards required for gas heat pumps for water heating.	8
Gas Heat Pump	Research into how gas heat pumps operate across different climates, with the end goal of understanding performance and producing lab / field tests for gas heat pumps.	7
Gas Heat Pump	Research into other configurations of gas heat pumps (i.e., combi-systems, CHP, PV integration, thermoacoustic, etc.), including the interoperability of controls for these systems.	7
Gas Heat Pump	Research into reducing cost for outdoor evaporators and other components of gas heat pumps.	6
Gas Heat Pump	Funding for demonstration of gas heat pump projects	5
Gas Heat Pump	Develop test procedures for renewable integration with gas heat pumps – e.g. solar assisted combined systems.	4
Gas Heat Pump	Research on defrost cycle for outdoor evaporators in cold climates.	3

Table 7-6 High Priority Space Heating and Water Heating Deployment Initiatives

Session	Initiative	Votes
CCHP	Release CCHP standards and develop a list of qualified technologies so utilities can move towards adopting the standards and equipment.	17
CCHP	Create 3rd party certification program for CCHP to ensure credible performance data.	17
CCHP	Create educational materials (with NRCan credibility) regarding high efficiency technology.	12
CCHP	Develop financial models for geothermal heat pumps that can reduce up-front cost of ground loops to customers through utility programs	11

Session	Initiative	Votes
	that have greater access to capital, spread risk across a larger installation base, and have convenient customer billing.	
CCHP	Develop test procedures, performance standards, education programs, incentives, and targets for combination electric heat pump systems (space and water heating).	11
CCHP	Enable 3rd party demonstration of CCHP performance and reliability, and provide communication materials (i.e., 1-2-page pamphlet) for consumers.	8
CCHP	Collaboration between HRAI, NRCan, and manufacturers on verified contractor training.	7
CCHP	Develop a design guide for selecting CCHP.	4
CCHP	Develop programs for dual-fuel heating solutions and conduct research into carbon reduction potential of dual-fuel products in real world applications.	4
CCHP	Provide sales tax exemptions for highest efficiency products.	4
CCHP	Develop design guidelines for installing and interfacing heat pumps with legacy heating systems.	4
CCHP	Provide whole house upgrade solutions in addition to CCHP support.	3
CCHP	Amend building codes to ensure proper credit of heat pump performance.	3
HPWH	Government should conduct national analyses to establish energy savings, performance, payback, and other data for electric and gas HPWHs.	26
HPWH	Develop midstream incentive programs to incentivize contractors to stock, market, and sell residential electric and gas HPWHs, and prepare tools to show the advantages with HPWH (i.e., higher profit for contractors).	12
HPWH	Improve contractor and builder awareness for residential HPWHs though wider training and support, performance-based building codes, and performance-based incentive programs.	10
HPWH	Develop labelling and other recognition programs to promote commercial electric and gas HPWHs, communicate the efficiencies of different technologies, and coordinate training and marketing to building designers and developers.	10
HPWH	Work with NRCan certified energy advisors to educate homeowners during audits and provide tools (i.e., decision tree) to educate homeowners.	5
HPWH	Increase the availability of gas HPWHs with lower installation complexity.	3
Condensing Storage Water Heaters	Provide incentives for contractors and distributors (midstream) and consumers (downstream) to cover both purchase cost and installation cost.	10
Condensing Storage	Develop program that proactively encourages consumers to consider water heater replacements and provides a matrix of savings data	9

Session	Initiative	Votes
Water Heaters	based on a variety of Canadian conditions (i.e., utility rates, water characteristics, number of occupants, etc.).	
Condensing Storage Water Heaters	Provide greater training for contractors that includes information from a 3rd party source that validates performance and savings data.	4
Condensing Storage Water Heaters	Develop performance-based codes that incentivize condensing storage systems, and codes that can help overcome trade-offs for drain water heat recovery, tankless models, etc.	4

7.4 Stakeholder list

A list of stakeholders who provided input during the workshops and interviews can be found in the tables below.

Table 7-7 Windows Stakeholders

Attendee Name	Organization	Workshop / Interview
Baigent, Ken	Arctic Energy Alliance	Deployment Workshop and Interview
Baker, Jeff	WESTLab/Fenestration Canada	Deployment and R&D Workshops
Bald, Gary	Loewen Windows	Deployment and R&D Workshops
Bellehumeur, Ekaterina	NRCan - Housing	Deployment Workshop
Bergeron, Lisa	Jeld-Wen of Canada	Deployment Workshop and Interview
Berkhout, Tom	British Columbia	Deployment Workshop
Bigras, Normand	Hydro Quebec	Deployment and R&D Workshops and Interview
Cochrane, Rosalyn	NRCan - Equipment Division	Deployment Workshop
Collier, Andy	PEI	Deployment Workshop
Daniels, Karen	Nova Scotia	Deployment Workshop
Delves, Katherine	NRCan - Equipment Division	Deployment Workshop
Do, Maggie	NRCan - Equipment Division	Deployment and R&D Workshops
Drew, Cam	Thermoproof Manufacturings Ltd.	Deployment and R&D Workshops
Ferguson, Alex	CanmetENERGY	R&D Workshop
Fevold, Brad	Marvin Windows	Deployment and R&D Workshops and Interview
Flannery, Patrick	Glass Canada	Deployment Workshop
Gamache, Jean-Philippe	Quebec	Deployment Workshop
Gareau, Cindy	Fenestration Canada	Deployment and R&D Workshops

Attendee Name	Organization	Workshop / Interview
Giroux, Erick	Novatech Doors	Deployment and R&D Workshops
Glouchkow, Jamie	NRCan - LEEP	Deployment Workshop
Glover, Michael	EcoTay	Deployment and R&D Workshops
Hagen, Rebecca	Minto	Deployment Workshop
Hamer, Gary	BC Hydro	Deployment Workshop
Hanson, Diana	American Architectural Manufacturers Association	Deployment Workshop
Hayden, Joe	Pella Corporation	Deployment Workshop
Hopwood, Steve	NRCan - Equipment Division	Deployment and R&D Workshops
Inks, Jeff	Window and Door Manufacturers Association	Deployment Workshop
Jackson, Eric	Quannex Building Products	Deployment Workshop
Kelly, Ryan	Efficiency Nova Scotia	Deployment Workshop
Kogovsek, Jean François	Maxam Inc	Deployment and R&D Workshops
Laouadi, Abdelaziz	National Research Council	Deployment and R&D Workshops
Larsen, Jim	Cardinal Glass Industries	Deployment and R&D Workshops
Lacasse, Michael	National Research Council	R&D Workshop
Lewin, Phil	GEM Windows	Deployment Workshop
Lingnell, Bill	Lingnell Consulting	R&D Workshop
Lis, David	Northeast Energy Efficiency Partnerships	Interview
Lundhild, Evelyn	Independent Electricity Systems Operator (IESO)	Deployment Workshop
Mantyla, Jack	Canadian Home Builders' Association	Deployment Workshop
McGowan, Alex	Levelton	Deployment Workshop
McIntyre, Sally	McIntyre Solutions	Deployment Workshop
Mikkelson, Mark	Andersen Corporation	Deployment Workshop
Milakowski, Eva	Ontario Ministry of Energy	Deployment Workshop
Mitchell, Jeff	Northwest Energy Efficiency Alliance	Deployment Workshop
Parekh, Anil	CanmetENERGY	R&D Workshop
Parrish, Dan	Pella Corporation	R&D Workshop
Pepin, Michel	Energi Fenestration Systems	R&D Workshop
Purdy, Julia	CanmetENERGY	R&D Workshop
Riopel, Gilbert	CLEB	Deployment and R&D Workshops
Roy, Raymond	Guardian Industries	Deployment Workshop
Sacilotto, Claudio	Sunview Patio Doors	Deployment Workshop
Scharf, Debbie	NRCan - Equipment Division	Deployment Workshop

Attendee Name	Organization	Workshop / Interview
Selkowitz, Stephen	Lawrence Berkeley National Laboratory	Deployment and R&D Workshops and Interview
Sharp, Gary	Canadian Home Builders' Association	Deployment Workshop
Shook, Cameron	Government of British Columbia	R&D Workshop
Spencer, Diane	New Brunswick Power	Deployment Workshop
Taylor, John	Consortium for Energy Efficiency	Deployment Workshop
Thwaites, Stephen	Morrison Hershfield	Deployment Workshop
Webb, Margaret	Insulating Glass Manufacturer's Alliance	Deployment Workshop
Wimmers, Guido	University of Northern British Columbia	Deployment Workshop

Table 7-8 Space Heating and Water Heating Stakeholders

Attendee Name	Organization	Workshop
Adbel-Rehim, Ayman	A.O. Smith Corporation	Deployment Workshop and R&D Workshop
Amankwah, Frank	NRCan - Equipment	Deployment Workshop and R&D Workshop
Bagshaw, Stephen	NTI Thermal	Deployment Workshop
Baigent, Ken	Arctic Energy Alliance	Deployment Workshop
Bains, Bea	FortisBC	Deployment Workshop and R&D Workshop
Bellavance, Marc-Antoine	Energir	Deployment Workshop
Berkhout, Tom	British Columbia	Deployment Workshop
Bernier, François	Association Provinciale Des Constructeurs D'Habitation Du Québec (APCHQ)	Deployment Workshop
Bernier, Michael	University of Montreal	R&D Workshop
Bigras, Normand	Hydro Quebec	Deployment Workshop
Bolger, Jim	Waterloo Energy Products	Deployment Workshop
Bonser, Greg	Independent Electricity Systems Operator (IESO)	Deployment Workshop
Boros, Joseph	Rheem Water Heating	R&D Workshop
Bos, Jim	ATCO Gas	Deployment Workshop and R&D Workshop
Carrier, Andre	Hydro Quebec	Deployment Workshop
Cincar, Andy	Daikin	Deployment Workshop
Cochrane, Rosalyn	NRCan - Equipment	Deployment Workshop and R&D Workshop
Collins, Kevin	NRCan	Deployment Workshop

Attendee Name	Organization	Workshop
Conn, David	ATCO Gas	Deployment Workshop
Cook, Ramsay	FortisBC	R&D Workshop
Corbin, Stephane	COMBEQ	Deployment Workshop
Daniels, Karen	Nova Scotia	Deployment Workshop
Davidson, Matthew	Efficiency Nova Scotia	R&D Workshop
Delves, Katherine	NRCan - Equipment	Deployment Workshop
Ferguson, Alex	CanmetENERGY	Deployment Workshop and R&D Workshop
Fernandes, Karl	Rheem Canada Ltd.	Deployment Workshop and R&D Workshop
Forsen, Martin	NIBE	Deployment Workshop
Froebelius, Randal	MARS (BOMA)	Deployment Workshop
Gamache, Jean-Philippe	Quebec	Deployment Workshop
Garrabant, Michael	Stone Mountain Technologies	R&D Workshop
Gaudet, Martin	NRCan - Housing	Deployment Workshop
Gervais, Tom	Bradford White Corporation	Deployment Workshop and R&D Workshop
Glouchkow, Jamie	NRCan- LEEP	Deployment Workshop
Gordon, Mike	UA Canada	Deployment Workshop
Hagen, Rebecca	Minto	Deployment Workshop
Hamer, Gary	BC Hydro	Deployment Workshop
Hammond, Dave	A.O. Smith Corporation	Deployment Workshop
Handal, Ramzi	iFlow	Deployment Workshop
Hikspoors, Paul	GIANT Factories Inc.	Deployment Workshop
Hosken, Bill	A.O. Smith Corporation	R&D Workshop
Kegel, Martin	CanmetENERGY	Deployment Workshop and R&D Workshop
Kelly, Ryan	Efficiency Nova Scotia	Deployment Workshop
Kobialko, Jim	FortisBC	R&D Workshop
Kriskapa, Senka	Government of Ontario	R&D Workshop
Kroeker, Chris	Northwest Energy Efficiency Alliance	R&D Workshop
Langevin, Partic	NRCan - LEEP	Deployment Workshop
Lesage, Jean-Claude	GIANT Factories Inc.	R&D Workshop
Luymes, Martin	Heating, Refrigeration and Air Conditioning Institute	Deployment Workshop and R&D Workshop
Ma, Wilson	Emerson Canada	Deployment Workshop
Masoumi Rad, Farzin	Union Gas	Deployment Workshop
McCrudden, Charlie	Daikin	Deployment Workshop
McIntyre, Sally	McIntyre Solutions	Deployment Workshop

Attendee Name	Organization	Workshop
Memory, Steve	A.O. Smith Corporation	Deployment Workshop and R&D Workshop
Milakowski, Eva	Ontario Ministry of Energy	Deployment Workshop
Mitchell, Jeff	Northwest Energy Efficiency Alliance	Deployment Workshop
Monney, Dominique	Emerson Canada	Deployment Workshop and R&D Workshop
Nichols, Jacinthe	Industries Dettson Inc.	Deployment Workshop
Picard, Isabelle	Natural Gas Technology Centre	R&D Workshop
Purcell, Bryan	Toronto Atmospheric Fund	Deployment Workshop
Purdy, Julia	CanmetENERGY	R&D Workshop
Pushpinder, Rana	Mitsubishi	Deployment Workshop
Reed, Scott	Stone Mountain Technologies	Deployment Workshop
Reitsmith, Stanley	UNKNOWN	Deployment Workshop
Sager, Jeremy	CanmetENERGY	Deployment Workshop
Scharf, Debbie	NRCan - Equipment	Deployment Workshop
Sharp, Gary	Canadian Home Builders' Association	Deployment Workshop
Shook, Cameron	Government of British Columbia	R&D Workshop
Stevens, Charlie	Northwest Energy Efficiency Alliance	R&D Workshop
Suami, Mvuala	NRCan - Equipment	Deployment Workshop
Taylor, John	Consortium for Energy Efficiency	Deployment Workshop
Thomas, Martin	CanmetENERGY	Deployment Workshop and R&D Workshop
Thompson, Steve	Taco inc	Deployment Workshop
Trant, Troy	Rheem Canada Ltd.	Deployment Workshop and R&D Workshop
Truskoski, Eric	Bradford White Corporation	Deployment Workshop
Tweedie, James	Canadian Gas Association	Deployment Workshop
Villarroel, David	NRCan - Equipment	Deployment Workshop
Warner, Bert	Robur	Deployment Workshop
Waters, Robert	CIPH	R&D Workshop
Weishuhn, David	Heating, Refrigeration and Air Conditioning Institute	Deployment Workshop
Well, Chris	NRCan	Deployment Workshop
Wensink, Danielle	FortisBC	Deployment Workshop
Whitehead, Terry	Enbridge	Deployment Workshop
Yilmaz, Sadettin	NRCan - Buildings and Industry Division	Deployment Workshop

7.5 Lower priority initiatives

Lower priority windows initiatives

Initiative L1 – Conduct market research into education and outreach programs to improve adoption

Stakeholders should conduct research into market acceptance issues for high efficiency windows, including cost, capabilities, thermal comfort, safety, durability, etc. This research would support industry efforts to educate customers on the benefits of high efficiency windows.

Initiative L2 – Conduct research to improve testing methods for determining window thermal and solar-optical performance

New window technology such as vacuum glazing, PV films, and integrated blinds and shades require test, simulation and rating procedures. Stakeholders should conduct research into the testing methods and simulation procedures for high efficiency window technologies.

Initiative L3 – Conduct data analysis of market trends to improve supply management and product positioning

Through a data collection and reporting initiative, the federal government could help support stakeholders by collecting and providing the data that could provide insights into window technologies (demand forecasts, compound annual growth rates, pricing, new technology trends [i.e., smart glass] etc.). These data packages could be valuable to manufacturers or builders when evaluating which product categories to manufacture or use. Furthermore, data reporting could help address potential window supply issues (i.e., shortage of flat/float glass) so that manufacturers of windows envelopes could better predict, manage and mitigate supply chain issues.

Lower priority space heating initiatives

Initiative L4 – Evaluate alternative heat pump designs for ultra-low energy home

As the efficiency of Canada's building stock improves with new construction codes and retrofits, the space heating requirements within the home change. Newer system designs, distribution architectures, and heating strategies may be more efficient or cost effective than traditional split-system ducted or ductless heat pumps. Stakeholders should conduct research to evaluate alternative CCHP designs and architectures, including new compressor technologies, air-to-water heat pumps, CO_2 heating-only heat pumps, and other technologies.

Initiative L5 – Provide information to support utility programs that incentivize contractors to stock high efficiency equipment

Many space heating systems are installed after failure of the existing system, and are often an emergency replacement in winter. As such, contractors and homeowners select technology that is readily available at the lowest cost. Higher efficiency technology is available in Canadian markets, but often in lower quantities, and typically requires a conversation with the homeowner about the long-term energy savings benefits of the higher efficiency models. Stakeholders should explore opportunities to incentivize contractors to stock high efficiency technology in inventory for use in emergency replacement scenarios. In addition, this concept could extend to local distributors who supply products to the contractors.

Initiative L6 – Conduct nationwide analysis to characterize customer willingness for heat pump adoption

Electric heat pumps can provide high efficiency and performance across Canadian climates, but there are several underlying factors that would affect heat pump adoption over time. For example, existing heat system type, climate, electrical infrastructure, and local utility rates affect the relative attractiveness of heat pumps for existing homes. Even with strong financial incentives from outside parties, customers would likely not change their space heating system unless the cost and complexity was manageable and advantageous for their future energy costs. Stakeholders should conduct a nationwide analysis to characterize the current Canadian building climate and identify the realistic market for electric heat pumps. This research would support manufacturer, utility, and contractor efforts to matching technology and solutions to the right customer segments. Beyond customers, the research could also consider contractor attitudes towards heat pumps since they are key influencers in homeowner decisions.

Initiative L7 – Provide information to support building code updates to accommodate gas heat pumps

Some gas heat pumps use an ammonia refrigerant in the outdoor unit to operate the absorption heat pump cycle. Ammonia has zero GWP, but has toxicity and flammability concerns, so manufacturers design their products to use a hydronic loop such that no ammonia ever enters the home. Today, most Canadian building codes limit the use of ammonia-based space heating systems for homes, which poses a significant barrier to greater adoption. Stakeholders should review the safety of gas heat pumps and building codes and revise applicable codes to allow for the safe use of gas heat pumps.

Initiative L8 – Develop heat pumps with hydronic loops to minimize risks from next generation refrigerants

The HVAC industry is transitioning refrigerant working fluids to those with lower GWP. Numerous research efforts are underway to identify promising low GWP refrigerants for building HVAC systems, but many of the options carry slight flammability and/or toxicity risks. Manufacturers could develop alternative heat pump designs that use a sealed refrigerant circuit in the outdoor unit and a hydronic loop to transfer heat to/from the building. Stakeholders should evaluate alternative system architectures, such as hydronic loops for split system heat pumps, in support of next generation heat pumps with low GWP refrigerants.

Lower priority water heating initiatives

Initiative L9 – Evaluate the reliability and longevity of gas HPWHs

Gas HPWHs entering the market must provide similar or better performance than conventional gas models to achieve wide acceptance. Conventional gas water heaters have a long record of high reliability and performance, even in hard water regions. Stakeholders should conduct research into the long-term reliability and performance of emerging gas HPWHs in conditions found across Canada to better evaluate their market prospects and identify future R&D needs.

Initiative L10 – Develop performance ratings, test procedures, and aspirational targets for advanced technologies that combine with conventional building systems

A number of advanced technologies could integrate with high efficiency products (e.g., solar PV integrated with electric and gas HPWHs), but there is limited standardized information to classify their

performance as an integrated system. Stakeholders should develop performance ratings, test procedures, and aspirational targets for advanced technologies that combine with conventional building systems (e.g., solar PV, mCHP, greywater heat recovery, etc.) to allow building designers, contractors, and owners to better evaluate these products and their abilities to achieve greater energy savings.

Initiative L11 – Conduct research to decrease the installation complexity for gas HPWHs

Gas HPWHs offer a high efficiency opportunity for gas water heating but face a number of market acceptance issues due to their installation complexity. Current models require larger footprint than conventional gas water heaters, dedicated airflow, an electrical connection, and other attributes that may require modifications to the home's infrastructure to accommodate the gas HPWH. Stakeholders should conduct research to reduce the installation complexity of the next generation of gas HPWHs for existing homes.

Initiative L12 – Develop programs to ensure the safe handling of next generation refrigerants

Electric and gas HPWHs use one or more refrigerant working fluids to transfer heat within the water heater system. Next generation refrigerants have lower GWP but may pose safety and flammability risks. Stakeholders should conduct research, training, and outreach to support the safe manufacture, installation, service, and use of electric and gas HPWHs using next generation refrigerants. These programs should update relevant product, safety, and building codes, labeling programs, training materials, and workforce education programs to ensure the value chain understands the risks and safe procedures for the new electric and gas HPWH refrigerants.

Initiative L13 – Develop a Canadian electric and gas HPWH manufacturing base

Canada has a domestic manufacturing base for today's water heating products, but currently imports high efficiency electric and gas HPWH products. Because the Canadian market is small relative to US and other markets, these products may not be designed to function in Canadian climates. Stakeholders should explore the possibility of a joint development with NRCan and Canadian manufacturers to develop a “native” electric and gas HPWH that would be designed specifically for the Canadian market.

Initiative L14 – Provide information to support the development of performance-based building codes that allow building designers to achieve greater energy efficiency through multiple options

Canadian building codes typically provide a prescriptive list of required building features, which often leads to contractors and builders using minimum efficiency equipment. Performance-based codes would establish a specific energy efficiency target that allows these parties to consider different building features as part of an integrated design process. Greater use of performance-based codes could allow increased adoption of high efficiency technology by providing designers options to reach the required building performance. In support of this goal, it would be important to ensure that new technologies could be modelled in NRCan’s modelling software.