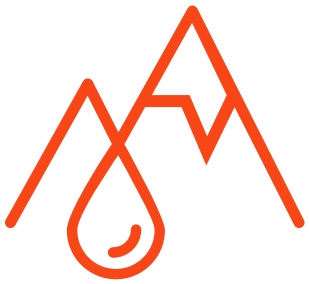

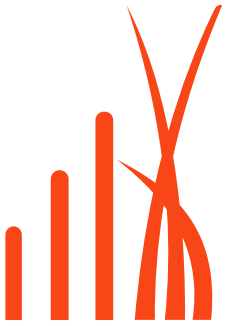

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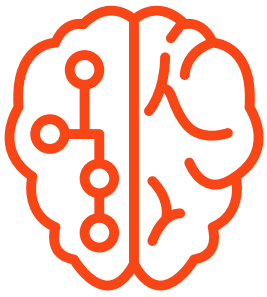

Green Retrofit Economy Study

TECHNICAL MEMO:
SUPPLY CHAIN READINESS

(June 2022)

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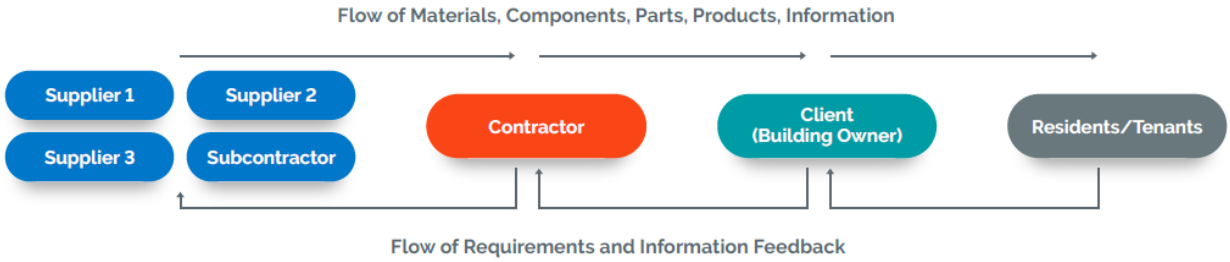
1. Retrofit products, technologies, and materials

The speed and depth of Canada's building retrofit activity will be dictated in part by the availability of low-carbon technologies and products. Today, the supply chain faces immense challenges, as unprecedented bottlenecks from the global pandemic and political unrest have resulted in material shortages, construction delays, rising costs, and other major disruptions. In this moment of supply challenges and climate crisis, there is an opportunity to redefine the building sector by shifting our focus to sustainable building technologies and products.

Figure 1. Elements of the supply chain for the retrofit industry



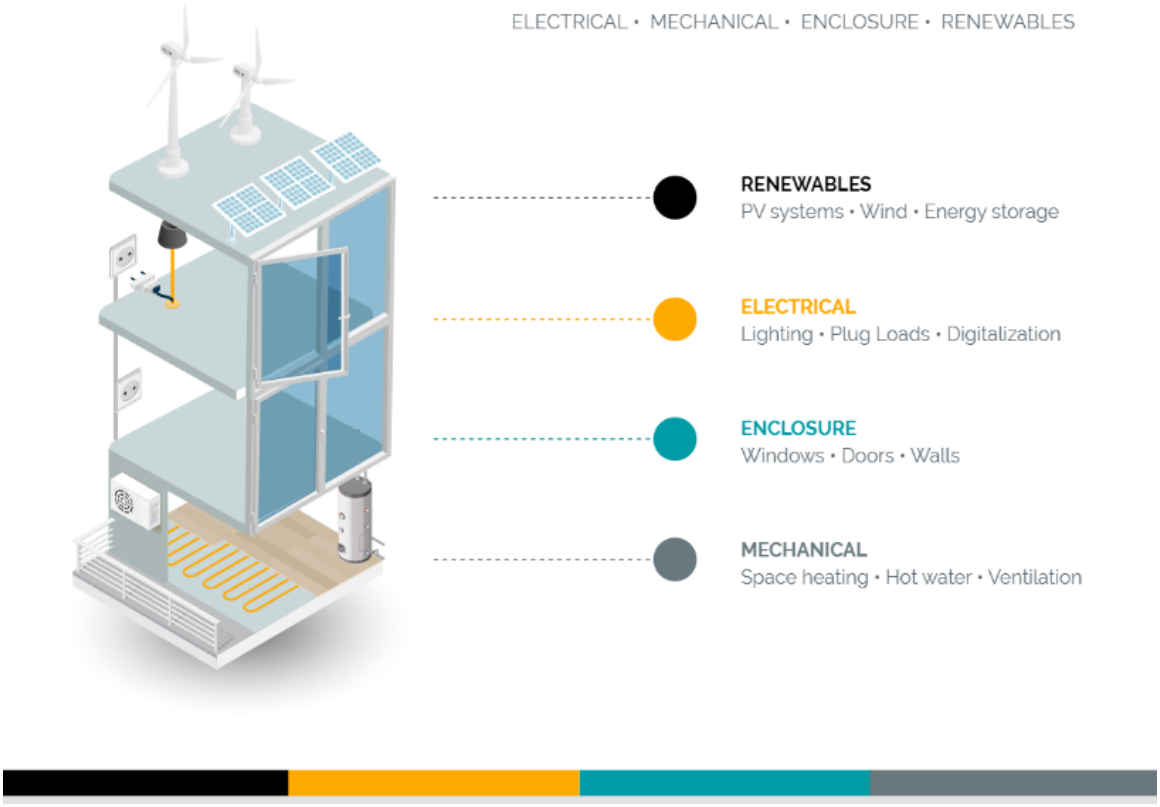
A stable low-carbon supply of technologies and products can decrease carbon emissions, improve the resilience of global supply chains, and bring about a more sustainable future; they will also deliver goods at competitive, predictable, and affordable prices in a reliable manner.

Many countries are taking steps to improve the availability and pricing of key technologies and products needed for decarbonization while also restricting the procurement of fossil fuel-reliant systems. European countries like Germany have introduced policies that will make heat pumps mandatory by 2024[1]. This is coupled with a ban on any new fossil fuel heating installations as of 2025. The US administration has delegated authority to the Department of Energy to utilize the Defence Production Act (DPA) to increase domestic manufacturing capacity of heat pumps, insulation, and solar panels.[2] In Canada, the federal government introduced a tax credit through budget 2022 for businesses manufacturing or procuring heat pumps.[3] They also allocated $192 million to the National Research Council-Construction Research Centre to work with industry for 7 years to develop and deploy technologies and tools for a carbon neutral construction sector. These actions all signal a move from governments to incentivize a transition to low carbon technologies and products and strengthen the supply chain for building owners undertaking deep carbon retrofits.

[1] Source: https://www.euractiv.com/section/energy-environment/news/germanys-summer-package-to-focus-on-heating-sector-revamp/
[2] Source: https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean
[3] Source: https://budget.gc.ca/2022/report-rapport/chap3-en.html

1.1 Technologies & Products by Retrofit Measure

Figure 2. Types of technologies and products by retrofit measures



The study describes examples of technical interventions grouped by building system (i.e., electrical, enclosure, mechanical, and renewable energy systems) to achieve energy and carbon reductions in the Canadian building stock. For each of the interventions, we selected individual technologies and products that constitute a single improvement towards retrofitting, and the relevant technology for each building system intervention.

Table 1. 1Retrofit Measures and Technology/Products by Building System

Building System	Sub-Building System Measures	Technology / Product
Electrical	Lighting	• LED lighting products • Lamps and Ballasts • Control systems for lighting and mechanical systems
	Plug loads/digitalization	• Building Automation System (BAS) • Premium Efficiency Motors • EV chargers
Enclosure	Windows/doors	• Clips and frames • Energy-efficient windows/ doors • High R-value Roll-up Receiving Doors
	Walls and roofs	• Insulation and air barrier systems • Reflective Roofs • High-efficiency curtain walls • Wall cladding systems • Thermal break technology
Mechanical	Space heating/cooling	• Air and ground source heat pumps. • Variable Air Volume (VAV) Systems • Airside economizer damper controls
	Hot water heating	• Electric high-efficiency domestic hot water • Modulating burners
	Air distribution systems Ventilation	• Heat and energy recovery systems • Demand controlled ventilation • Piping ductwork • Distribution system insulation
Renewables	Renewable energy system	• PV systems • Solar domestic hot water • Building Integrated Photovoltaics • Hybrid (Wind and Photovoltaics) • Energy Storage

Artificial Intelligence (AI) in Building Retrofits

Integrating AI into retrofit products and technologies is a new trend that is bound to unleash great opportunities for energy efficiency and emission reductions in buildings. There is currently select number of AI technologies introduced that have proven to significantly improve operational efficiencies while enhancing building systems. AI has found its way into Building Automation Systems (BAS), where it manages all building operation functions and meets user expectations without humans. Once the supply for AI technologies becomes available across the country, we anticipate no major barrier to the integration and scalable uptake.

2. Readiness evaluation

The readiness of key technologies and products will either accelerate or inhibit the market's capacity to undertake low-carbon retrofits. For the assessment of market readiness, this study was informed by the methodology developed by the Canadian federal government and Navigant Consulting to evaluate barriers to energy-efficient products. This methodology, called the 5A's framework,[4] is used successfully in Canada to design effective market transformation programs for residential, commercial, and industrial products. The results presented focused on three steps in the value chain from manufacturer to end user; awareness; availability and affordability for which there was sufficient information to conduct an assessment.[5]

1. **Awareness:** The knowledge and capacity of market participants (i.e., distributors, retailers, designers, electrical contractors, and end-users) to specify, construct, and operate products and technology. Is the market aware of the technology? What is the overall level of awareness among all market players with respect to the more efficient technology being evaluated?
2. **Availability:** The ability of the market to procure the product or technology for use in Canada. Does the technology exist? What information or policy mechanisms are available to support and promote the adoption of the given technology?
3. **Affordability:** The cost of the product or technology as compared to its conventional alternative. Is the market able to bear the selling price? Does the higher purchase price of the more efficient technology represent a market barrier? Some sectors (e.g., residential) can be particularly cost-sensitive, while others (e.g., commercial) are more likely to look at life-cycle costs and payback periods.

[4] Based on Five A's: Barrier Classification and Market Transformation Program Design for Energy Efficient Technologies. Source: https://www.aceee.org/files/proceedings/2004/data/papers/SS04_Panel6_Paper10.pdf

[5] Data was collected through interviews, a workshop and 2 focus groups. Information collected was corroborated with secondary research. The study was unable to gather sufficient data through the stakeholder engagement and research phase to effectively respond to the two remaining factors in the 5As model: accessibility and acceptance.

Legend:
● : High ◑ : Moderate ⊘ : Low/None

Table 2. Readiness Evaluation of Technologies and Products in a Deep Retrofit

Technology/Product	Awareness	Availability	Affordability
Electrical			
LED lighting products	●	●	●
Lamps and Ballasts	●	●	●
Building Automation Systems (BAS)	◑	●	◑
Premium Efficiency Motors	●	●	●
EV Chargers	◑	◑	◑
Enclosure			
Clips and frames	●	●	◑
Energy efficient windows/doors	◑	●	◑
High R-value Roll-up Receiving Doors	⊘	⊘	⊘
Insulation	●	●	◑
Reflective Roofs	◑	●	●
High efficiency curtain walls	⊘	⊘	⊘
Wall cladding systems	⊘	⊘	⊘
Thermal break technology	◑	●	◑
Mechanical			
Heat pumps	◑	◑	◑

Variable Air Volume (VAV) Systems	✓	✓	✓
Airside economizer damper controls	✓	✓	✓
Electric high efficiency domestic hot water	◑	◑	◑
Modulating burners	✓	✓	✓
Heat and energy recovery systems	✓	✓	◑
Demand controlled ventilation	✓	✓	✓
Piping and duct work	✓	✓	◑
Distribution system insulation	✓	✓	✓
Renewables			
PV systems	◑	◑	◑
Solar domestic hot water	◑	◑	◑
Building Integrated Photovoltaics	◑	⊘	⊘
Energy Storage	◑	⊘	⊘
Hybrid (Wind and Photovoltaics)	⊘	⊘	⊘

Table 7 demonstrates that all five electrical technologies except Electric Chargers have high or medium-high market readiness in Canada. The market readiness of the Enclosure technologies can be averaged as medium because the availability and affordability of the High R-Value Doors and the awareness of the High-efficiency Curtain Walls are low. 5 out of 9 of the Mechanical technology/products have high market readiness. On the other hand, renewable technologies have the lowest market readiness evaluation.

For all building system interventions, there will be technologies and products that will require interventions to build the capacity of the industry such that they have the knowledge and skills to sell, specify, design, install, commission, and operate the key technologies. In some instances, this may also include public awareness campaigns that target consumers. BC Hydro in British Columbia has prioritized education on heat pumps, connecting with homeowners through print media, online and television commercials.[6] Whereas heat pumps may represent the first phase of awareness-raising and education for both consumers and the industry, this study confirms that other building systems will require the same attention. In particular, interventions that improve the performance of building envelopes, such as high-efficiency curtain walls and wall cladding systems. While renewables have had a longer established presence in many markets in Canada, the move towards decarbonizing the grids is elevating the importance of Grid-Interactive Efficient Buildings (GEB)[7] that can be sources and storage systems for renewable energy – e.g., building-integrated photovoltaics and batteries.

Similarly, as it relates to the availability of technologies, there is a role for industry associations and governments to identify and ensure the market has access to a range of products to deliver on low carbon retrofits. Many products that have been available in Europe and Asia for decades are not available in Canada, as is the case for some cold climate heat pumps.

Pricing or the affordability of technologies can be a significant deterrent to the integration of low carbon measures in retrofits. Many of the products and technologies that the market will rely on are more costly than their conventional counterparts. However, Canadian demand for low-carbon technologies is expected to double through 2030, compared to today's levels: with the size of the clean technology investment opportunity reaching a cumulative $184 billion from 2020 to 2030. Investments in low-carbon technologies related to building efficiency and electrification are expected to climb from $2.5 billion to $3.5 billion annually through 2030, or a 42% increase from the 2020 period.[8] Increased demand is likely to result in cost compression, but government or bulk procurement is another vehicle for reducing costs.

2.1 Overview of market readiness of key technologies and products

While more than 25 technologies and products were identified as directly relevant to low-carbon retrofits (as listed in table 2), six key building technologies and products stood out as having greater relevance to the future of building improvements. The priority technologies and products were defined and validated through interviews and two stakeholder workshops. The stakeholders also identified that the retrofit market would benefit from increased awareness, access, and cost optimization to enable greater uptake.

[6] Source: https://www.bchydro.com/powersmart/residential/building-and-renovating/considering-heat-pump-info-tips.html
[7] The US Department of Energy defines a grid-interactive efficient building (GEB) as "an energy-efficient building that uses smart end-use equipment and/or other onsite Distributed Energy Resources (DERs) to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way."
[8] Source: https://institute.smartprosperity.ca/sites/default/files/report-growingclean.pdf

Table 3. Description of key retrofit technologies and products

Technologies and Products	Description
Building automation systems (BAS)	A building automation system (BAS) is an intelligent system that connects the heating, venting, and air conditioning systems (HVAC), lighting, and security to communicate on a single platform, optimizing building performance. Over the last two decades, BAS has emerged as a key tool to advance energy savings and carbon reductions by running equipment only when necessary; operating the equipment at minimum capacity and minimizing the peak electricity demand.[9] The problem is not that the industry is unaware of efficiency gains from implementing BAS; it is the lower adoption rates. Using US data, currently, only 42% of the total commercial floor space is served by a BAS. Smaller buildings or Class B & C are rarely fitted with BAS despite complex energy management challenges and significant energy efficiency potential. [10]The barriers to adoption include the high implementation cost and reliance on skilled building managers and operators to leverage the technology in service of the efficiency goals.
Heat Pumps	Heat pumps are high-efficiency heating and cooling systems. The two primary types of heat pumps are ground source or geothermal heat pumps (GSHPs) and air source heat pumps (ASHPs). What sets them apart is where they source their heat from: GSHPs transfer heat from the ground, while ASHPs transfer heat from the air. Heat pumps are available for every major building type, including apartment-style residential, small to medium commercial, and larger commercial and institutional buildings. Air-to-water, and cold climate air-source heat pump technology do exist, but the number of options available in the North American marketplace is still very limited. High-efficiency electric technology for central domestic hot water applications is less widely available, especially for larger commercial and institutional applications.[11] In the case of retrofits, the installation of GSHPs may be limited to parking lots since commercial properties are often in densely populated areas without adjacent green space to drill wells. Installing GSHPs may be reliant on equipment that can be operated in smaller spaces and limited ceiling heights, which in turn is reliant on e skills that are not widely available.

[9] Source: https://www.lntinfotech.com/blogs/building-automation-system-for-sustainability/#
[10] Source: https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS_2018_Building_Characteristics_Flipbook.pdf
[11] Source: https://www.zebx.org/wp-content/uploads/2021/04/BC-Building-Electrification-Road-Map-Final-Apr2021.pdf

Heat and Energy Recovery Systems	Heat recovery systems extract heat from sources of energy that would otherwise be considered waste heat (e.g., heated air vented out of a building for cooling or air quality purposes, chillers, industrial processes that require extremely hot water or steam, hot water drains, and sewage). Technology for heat capture and recovery is readily available for all major building types. However, it can be costly to install and is not common practice in the design of retrofits.
Wall cladding systems	Wall cladding systems for retrofits fall into two categories: recladding and overcladding. Recladding refers to removing and replacing the existing exterior wall assembly. Overcladding typically involves laying material over another material to form a 'skin' on the walls to increase efficiency. Wall overcladding systems such as Exterior Insulation and Finish Systems (EIFS) have been in use for commercial retrofits for some time however they are most effective on buildings with opaque wall surfaces that comprise of half or more or the envelope. Recladding systems can apply to all building typologies -even those with glass-heavy curtain walls. Buildings seeking to improve the performance of their building through recladding may find that solutions are not widely available, costly to procure and install and disruptive to existing tenants.13 They are not in use across the industry despite being associated with substantive carbon and energy savings.
Building Integrated Photovoltaics	Building-integrated photovoltaics (BIPV) are solar power generating products or systems seamlessly integrated into the building envelope and part of building components such as façades, roofs, or windows. While BIPV continues to see substantive market growth in Europe and the United States, it still has not been widely adopted in Canada and is not often considered in retrofit designs[12].
Energy Storage	Thermal energy storage works as an HVAC 'battery' for a building. It can store and recover thermal energy, charging and discharging depending on building operations. Energy storage systems are not yet widely available or cost-effective in the Canadian marketplace. Typically considered for large commercial and industrial buildings, battery systems provide an opportunity for peak demand management and can increase resiliency by offering backup power during an outage.

[12] Source : https://www.nrel.gov/docs/fy00osti/25272.pdf

Materials and Embodied Carbon

While retrofit pathways enable the operational emission reductions from a deep retrofit, the embodied carbon of the materials leveraged for performance improvements cannot be discounted. About 10% of Canada's annual CO2 emissions are from the manufacturing, transport, and processing of construction materials, as well as those used for the refurbishment of buildings and transport infrastructure. Materials with high embodied carbon (such as cement, steel), and fossil fuel use contribute to the majority of the CO2 emission in the construction phase.

To date, efforts to quantify and reduce the embodied carbon of buildings have focused mainly on structural and enclosure materials – primarily wood, concrete, and steel. While these materials are most often considered in discussions on zero-carbon new construction, there is still a reliance on core enclosure materials in the refurbishment of a building. These materials represent a significant portion of overall embodied carbon and offer opportunities for cost-effective reductions. Additional

2.2 Enabling Services

As the retrofit market grows, there are services needed to support low carbon renovations at scale. These include models for aggregation and standardization, as well as monitoring and verification.

The investment thresholds, cost-compression, and the climate imperative require the market to consider how it can identify and aggregate multiple projects for financing. For example, the minimum threshold for the Canada Infrastructure Bank's (CIB) *Commercial Building Retrofit Initiative* is $25 million. An investment of this size would be typical of at least 25 projects. Models for aggregation are emerging and include portfolio-wide approaches by large commercial owners.[13] They may undertake a horizontal aggregation approach whereby they bulk purchase a key technology such as lighting or heat pumps and apply it across their buildings. A second aggregation approach could be brokered by turnkey providers such as Energy Service Companies (ESCOs), engineers and contractors, municipalities through commercial property-assessed clean energy (C-PACE), utilities through on-bill repayment, third-party investment vehicles, or property management firms. In these scenarios, projects are identified and collected from multiple owners and onboarded through a unified process.

Standardization, monitoring, and verification services have never been more important as owners seek pathways to secure emissions and energy savings that are in alignment with financing requirements and climate targets - investors seek tangible evidence of their investments that result in the environmental benefits promised. The CIB requires the investor Ready Energy Efficiency[14] certification to standardize the retrofit planning process and validate that the planned energy and carbon savings align with the Energy Conservation Measures (ECMs) identified. This provides the groundwork for monitoring and verification upon completion of the project. These approaches are reliant on engineering services such as energy modeling as well as data collection and reporting post-project completion.

[13] Source : https://drdrc6dlee0yd.cloudfront.net/files/Investment/EN/Public-Retrofits-Initiative-Overview.pdf
[14] Source : https://www.cagbc.org/our-work/certification/investor-ready-energy-efficiency/

ESCO Model

An Energy Services Company (ESCO) mitigates the technical and performance risks by designing and implementing retrofit interventions that provide a financial guarantee to project lenders/owners that the energy savings generated will cover the debt service. ESCOs get repaid from the savings and once repaid, the retrofitted systems and savings accrued are handed back to the building owners.

Super ESCO Model

A super ESCO is an organization that is supported by government and private sector investors to secure retrofit projects and service them through a network of ESCO delivery partner. As a project aggregator, they also help overcome barriers to retrofits by undertaking business development activities such as launching calls for tenders on behalf of clients as well as capacity building for the industry through retrofit training. Since they take on financial and technical risks, this enables ESCO to advance deeper emissions and energy saving measures.

SOFIAC (Société de financement et d'accompagnement en performance énergétique) is Canada's first Super ESCO. It was launched in January 2021 and is the largest energy efficiency initiative of its kind in Canada, providing financing for commercial, industrial, and multi-residential buildings to undertake energy-efficient infrastructure upgrades. It also provided turnkey solutions to energy efficiency projects, including design, implementation, and monitoring supports. The energy cost reduction target for all projects funded through SOFIAC ranges from 25 to 40 percent, which could reduce greenhouse gas emissions by 30 to 50 percent.

Energiesprong, is a mass retrofit model developed in which:

- Project management for multiple buildings is assigned to a single market development team rather than loaded onto individual owners.
- Energy savings and home comfort improvements are guaranteed rather than estimated.
- Users are treated like a community rather than individual buyers.
- New supply chains and markets are "shaped via high-volume orders for integrated measures, with manufacturing offsite.

The Energiesprong was originally developed in the Netherland but there have been adaptations of it in the US and Canada. The Canadian examples include Halifax Gut Rehab Income property, Passive House Reno Gagetown NB, PEER: Pre-Engineered Exterior Retrofit, Kestrel Court Residence, NZE Retrofit Pilot, and the Pembina Institute's Reframed Lab. The Enrgiesprong projects are also found in Toronto, Quebec and 14 municipalities in Nova Scotia.[17]

[15] Source : https://ecologyaction.ca/sites/default/files/images-documents/issue_areas/BFH-%20EAC%20Retrofits%20%281%29.pdf

3. Supply Chain Challenges & Opportunities

The COVID-19 pandemic and the war in Ukraine put a spotlight on the impact that global supply chains can have on the decarbonization of our building sector. Shortages in building supplies and price spikes drove up project's rebuilding costs, and timelines; it also affected companies ranging from contractors to insurers. What is clear is that the demand for low-carbon technologies and products will continue to grow. In fact, the heat pump market alone is expected to expand in North America for both regular and cold-climate heat pumps from $1.46 billion in 2022 to $3.31 billion in 2031 at a compound annual growth rate of 9.6%[16] There are several actions that can strengthen the development of low-carbon technologies and product supply chains. These include a combination of awareness-raising, skills development, market support and innovation:

Table 4. Action themes, associated challenges, opportunities, and action leads that contribute to the development of low-carbon supply chains

Theme	Challenge	Opportunity	Lead
Awareness	No wide-spread awareness of key technologies and products needed to enable lo carbon retrofits. This limits adoption rates.	Build awareness of priority technologies, products, and materials for use in retrofits with a broad suite of professionals including owners, designers, the construction industry and building operators.	Professional and Industry Associations
Skills and Competencies of Workforce	Shortage of entry-level labour to keep pace with anticipated retirements, as well as increased demand from a dynamic market.	Connect skills development with priority technologies, products, and materials to ensure that they are properly integrated into designs, installed in the construction process, and operations to secure performance expectations.	Educators
Technology and Product Availability	Key technologies and products needed to meet the demand for low carbon retrofits are not available	Work with manufacturers to expand the availability of key products and technologies for low carbon retrofits	Government and Industry

[16] Source: https://guidehouseinsights.com/reports/Cold-Climate-Heat-Pumps

Technology and Product Pricing	Many technologies and products are cost-prohibitive to source	Advance low carbon procurement policies that strengthen demand for low carbon products and over time reduce costs. Bulk purchasing by large owners. Subsidies for low carbon technologies	Government and Industry
Low Carbon Construction Materials	Low carbon material sourcing is limited, and sourcing products can be challenging	Funding life cycle assessments and environmental declarations for products manufactured by small- and medium-sized companies as well as funding whole-building life cycle assessments for large buildings.	Government and Manufacturers
Supply Chain	While Canada will continue to rely on the global supply chain, there are limitations in the domestic supply chain impacting retrofit decisions today	Define a Buy Clean Strategy that will enable public and private procurements to use Canadian-made low-carbon materials.	Industry Associations and Government
Supply Chain	Absence of a coordinated approach to securing a low carbon supply chain that is capable of meeting the needs of the building sector	The Canada Green Buildings Strategy should provide a roadmap on how to decarbonize buildings by 2050 and must address the gaps in skills development and supply chain	Government