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Canada's Opportunity Playbook: Pathways to Strategic Decarbonization

BUILDINGS





Buildings are essential to the comfort, health, and economic productivity of Canadians. As climate change intensifies, the importance of building cooling and ventilation during heat waves and wildfire season is growing.

9. Buildings

Function	Structures including residences, places of business, schools, hospitals and other public facilities.
GHG emissions	81 Mt CO ₂ e (2024); 12% of total national emissions. 38 Mt CO ₂ e residential; 43 Mt CO ₂ e commercial and institutional buildings.[61]
Options for decarbonization	Decarbonization Pathways: Air and ground source heat pumps. Bridge Pathways: Dual fuel (hybrid) heat pumps. Niche Pathways: Electric furnace heating, hydrogen, renewable natural gas, biomass. Enabling Pathways: Net-zero design, retrofitting for energy efficiency, district energy systems, solar panels on buildings.
Stage of transition	Emergence: Design, construction and retrofitting of net-zero buildings. Early diffusion: Individual technologies such as heat pumps.
Current obstacles	Cheap natural gas; capital cost of low-carbon equipment and building renovations; shortage of trained workforce; insufficient incentives and coordinated standards driving innovation; entrenched industry practices.
Other systemic issues	Affordability of housing; lack of public housing; electricity options for remote communities; construction-related waste; developer-dominated urban planning; little real estate industry interest in energy performance.

Opportunities and concerns	Opportunities: For consumers, lower long-term energy costs and improved indoor air quality and comfort. For economic development, jobs in low-carbon construction and retrofits; domestic manufacturing of net-zero equipment, growth in green real estate and low-carbon materials. Concerns: For consumers, high upfront costs, affordability challenges for low-income and households. For economic system, workforce shortages, financing barriers, slow industry adoption, electricity system constraints, stranded gas asset risks, and limited scalability of some alternatives.
Priorities for action	Raise standards for new construction through progressive adoption of net-zero building codes; accelerate electrification and retrofits in existing buildings through heat pump deployment, district heating, and energy efficiency upgrades; promote heat pumps over other heating and cooling systems through incentives, regulation, education and training; mandate building emissions performance standards and labelling; build financing capacity and drive innovation to mobilize private capital and scale emerging clean technologies; train Canada's labour force for low-carbon building design, construction, retrofit and maintenance.
Longer-term issues	Affordable net-zero housing; managed phase-out of fossil fuel infrastructure; reduced embodied emissions in construction and retrofitting; construction waste reduction and circular material use.
Indicators of progress	Share of electricity in building energy consumption; share of the building stock using heat pumps for heating and cooling; annual retrofit rate; transparency around embodied carbon in building materials.



9.1.1 Current Status

Buildings are essential to the comfort, health, and economic productivity of Canadians. As climate change intensifies, the importance of building cooling and ventilation during heat waves and wildfire season is growing. This isn't just a matter of comfort. In 2021, 619 heat-related deaths were reported in B.C. during a one-week extreme heat event, and those affected were largely vulnerable populations without access to cooling.[312]¹

The building sector contributes to GDP directly through real estate, rental, and leasing income (13% of Canada's GDP) and indirectly through the construction industry (7% of Canada's GDP, although this figure includes infrastructure construction as well as buildings).[305] Real estate, rental, and leasing markets are concentrated in key metropolitan areas. The construction industry employed 1.2 million people in 2024, or 6.5% of the workforce.[314]

It is useful to distinguish residential properties from commercial and institutional premises at the outset, as the two sectors differ in ownership structure, financing, energy use patterns, and the social pressures they face. However, when it comes to decarbonization, the two share many of the same challenges, solutions, and policy levers.

Residential buildings

There were 16.4 million dwellings in Canada in 2022.[307] Over 200,000 new homes are built each year as the population continues to grow, the majority of which are apartments.[316,317] In 2021, more than 66% of Canadian families owned their own home, and more than half of those households (60% in 2021) were paying off a mortgage.[318] Single detached houses represented 53% of all dwelling types in 2022,[307] but with the rise of apartment-based households, this share has been declining for decades. Figure 25 displays the breakdown of residential buildings by type in 2022.

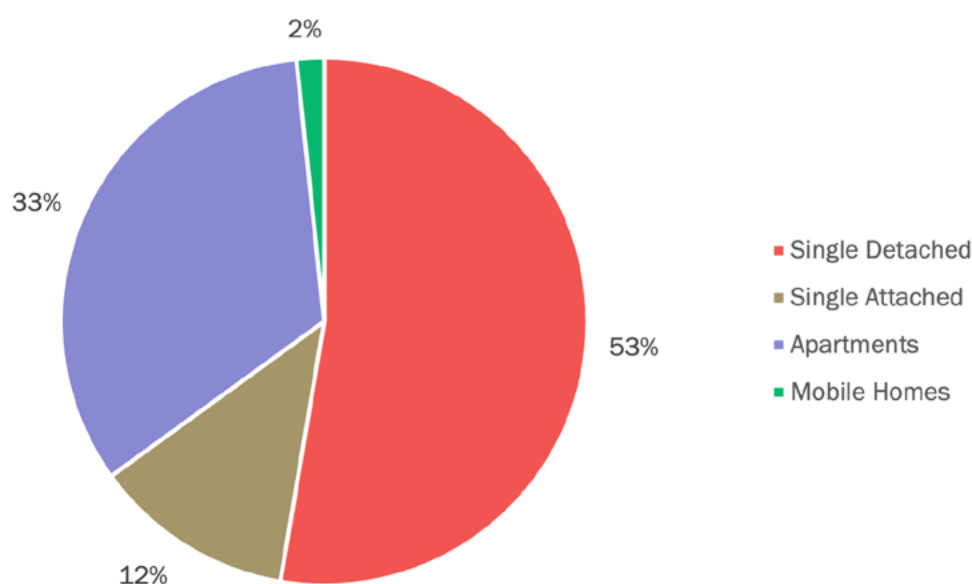


Figure 25. Residential buildings by type, Canada 2022[315]

¹ All noted references can be found in the full Playbook document.

For low-income households, renting is often the only affordable housing option, and large investment firms and property management organizations own a significant share of rental properties. These large firms are shown to charge premiums compared to other types of landlords. In Toronto, these premiums are most extreme for lower-income and racially marginalized areas.[319] Across the country, 45% of Canadians are concerned about the affordability of housing.[320]

In recent years, house prices have risen faster than household income. While the median after-tax Canadian family income increased by 4.5% between 2019 and 2023,[321] house prices grew by 17%.[322] According to the OECD, Canada's house price-to-income ratio was the second highest among the reported countries in 2024. Shelter was the largest item on household expenditures in 2023, accounting for 32% of the total consumption,[323] and mortgage debt is responsible for three-quarters of the debt burden on Canadian families.[324]

Although household energy costs such as water, fuel, and electricity account for less than 3% of total annual expenditures on average, they still pose a significant burden for many.[323] Studies estimate that nearly 2 million Canadian households struggle with high energy costs.[325] Nevertheless, Canada has some of the lowest residential electricity pricing in the world. Modelling by Electrifying Canada showed that adopting heat pumps and electric vehicles will be better for most Canadian households in the long term. Their analysis found that roughly 70% of households

will spend less on energy by 2050 because efficiency gains will more than compensate for electricity rate increases as grids expand, with electric vehicles being a key driver of those savings.[115]

There are significant regional differences in the fuels used for residential space and water heating. Most Quebec homes use electric resistance heating and Atlantic provinces primarily rely on electric resistance or heating oil. Meanwhile, lower cost natural gas is a dominant source of home heating in Ontario, the Prairies, and British Columbia.[326] Energy use in the residential sector increased by only 5.5% from 2000-2022 (despite a 32% increase in the number of households). This indicates steady improvements in energy efficiency, which can be attributed to modernization of building codes in some jurisdictions, the adoption of LED lighting across Canada, and improvements in the efficiency of air conditioners, furnaces, and appliances.[327,328]

Commercial and institutional buildings

There were more than 560,000 commercial and institutional buildings in Canada in 2019.[329] The floor space of commercial and institutional buildings has risen by 27% since 2000 as Canada's economy has grown, and international companies continue to expand in Canadian cities.[320] Office buildings, non-food retail stores, and mixed-use buildings made up the biggest shares of non-residential buildings in 2019, accounting for 18%, 14%, and 11%, respectively.[329] Figure 26 displays the share of commercial and institutional buildings by primary activity.

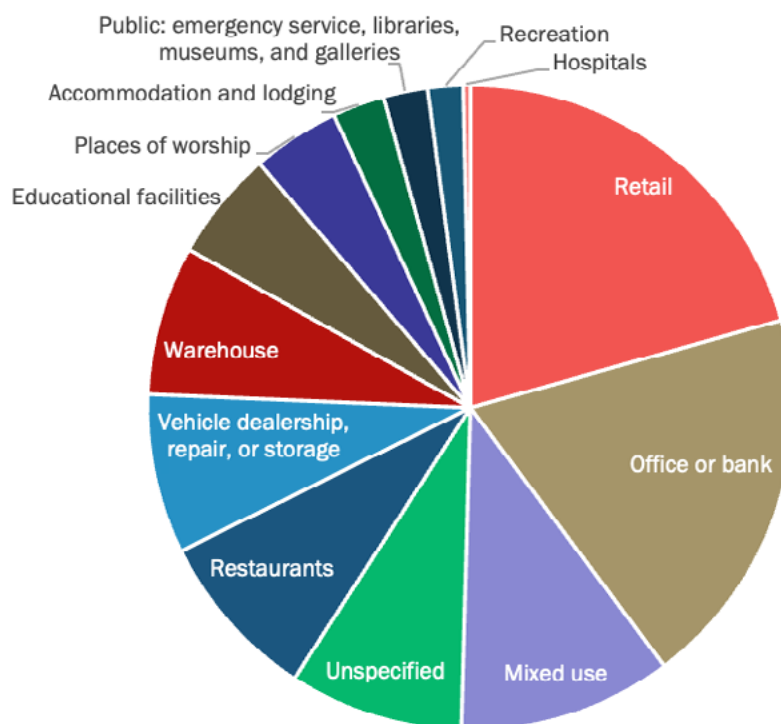


Figure 26. Commercial and institutional buildings by use, Canada 2019[322]

Commercial buildings are generally owned by private investors, and office and retail rents have surged by about 20% across Canada between 2018 and 2024, even as occupancy has continued to fall. One explanation is that tenants increasingly demand premium features, allowing landlords to maintain high rents to recover costs despite vacancies. [321] At the same time, the push for return-to-office policies and the high cost of new construction are expected to increase demand for existing spaces, reinforcing the trend of high prices.[331]

Commercial real estate financing comes from a variety of institutional sources including banks, insurance companies, investment firms, pension funds and credit unions, with some larger players holding significant market share. There are few restrictions on foreign ownership, and major players include firms from Europe, the U.S. and China.[332]

Natural gas is the dominant fuel for commercial and industrial space heating across Canada, but there are regional differences. Just over half of space heating energy comes from light fuel oil and electricity in Atlantic Canada, while electricity provides nearly a third of space heating in Quebec. Alternatives to natural gas are minor contributors to commercial and industrial space heating in all provinces west of Quebec.

9.1.2 Nature of the Problem

Buildings accounted for 12% of Canada's total GHG emissions in 2024 (81 Mt of CO₂e).[186] Approximately half of this came from the residential sector (38 Mt), and half from the commercial and institutional sector (43 Mt). Since 1990, residential emissions have decreased by 15%, realized through measures such as building envelope upgrades, adoption of higher efficiency appliances, and fuel

switching. Emissions from the commercial and institutional sector have increased by 57% since 1990.[186] Building sector emissions arise from onsite burning of fossil fuels such as natural gas and heating oil, primarily for space and water heating.

In addition to direct combustion-related emissions, buildings are associated with other sources. Emissions can arise from electricity generated to power buildings and from the hydrofluorocarbons (HFCs) used in air conditioners, fridges and heat pumps. Emissions produced during the construction phase and production of building materials (steel, concrete, plastic and so on) are considered embodied carbon. As operational emissions from buildings decline, embodied carbon in construction materials (for new builds and retrofits) becomes an increasing share of lifecycle emissions from buildings.[333]

Low-cost natural gas

The relatively cheap cost of natural gas in Canada discourages investment in energy efficiency (building insulation, more efficient heating units) and fuel switching to electricity. Energy efficiency is not a high priority for consumers when they choose a home or consider value-added renovation to an existing property. Similarly, commercial and institutional building owners and managers have paid relatively little attention to monitoring energy performance. Natural gas and electricity prices vary from province to province, but the relatively low gas prices in Ontario and Western Canada make displacing gas a challenge.

Since Canada is a large natural gas producer, this issue is also politically charged. In some provinces, decisions to expand gas infrastructure risk creating stranded assets whose costs will ultimately fall on ratepayers as the transition to a low-carbon economy proceeds.

Financing challenges

Financing the upfront costs for energy retrofits and fuel switching is challenging, even when payback periods are short, largely due to high household debt levels and a lack of dedicated financing mechanisms. In buildings that are rented or leased and where tenants pay utilities, there are few or no financial benefits to investing in energy retrofits or fuel switching even when these are cost effective. This can exacerbate the affordability challenges for renters. In 2022, 34% of renters in market rental housing were paying more than 30% of household income on shelter costs.[334]

Additionally, the financial benefits of residential electrification are less accessible for households without vehicles, who are disproportionately lower income, as they cannot realize the significant cost savings associated with electric vehicles. As a result, their overall energy savings from electrification are more limited.[115]

Upfront costs are also a problem for the commercial and institutional sectors, who often do not prioritize the sometimes-significant capital investments needed to decarbonize their buildings. Unlike residential property owners who often rely on individual mortgages or home energy grants, commercial project developers must engage institutional actors to fund retrofits or new low-carbon construction. The scale and timeline of these investments, along with risk aversion among capital providers, create additional financing barriers.

Slow retrofit schedules and turnover of building heating systems

Building decarbonization is also constrained by the slow turnover of building stock and heating equipment. In the residential sector, the pace of deep energy retrofits remains far below what would be required to decarbonize the existing stock. For example, the Greener Homes Grant

supported only 29,000 deep energy retrofits over five years,[335] while more than 6.5 million homes built before 1984 and 2.5 million before 1960 will require major upgrades.[336] In the commercial and institutional sector, where heating systems often have longer lifespans (often 15-25 years), buildings may already be locked into high-carbon equipment beyond 2050. Since low-carbon heating systems are most cost-effectively installed when older systems are at end-of-life, slow replacement cycles can delay the transition unless action is taken well in advance.

Other issues

The construction sector plays a significant role in building emissions through material choices, construction practices, and the specification of appliances. However, decarbonization is complicated by the sector's structure: although some large firms operate in the market, much of the industry consists of small firms and independent contractors. This fragmentation makes it harder to coordinate and adopt new approaches at scale, contributing to a general hesitancy to take risks on unfamiliar technologies or practices. There is also a growing skilled trades shortage, with an estimated 56,900 new green construction workers needed between 2023-2032 to meet Canada's emissions targets in the residential sector.[337]

Overall, in the past few decades, building energy efficiency and GHG emissions have been a secondary concern in the commercial, institutional, and residential sectors. Given today's relatively inexpensive energy prices and permissive regulatory environment, there has been little incentive for change.

9.1.3 Net-Zero Pathways

A transition to a net-zero building sector requires the elimination of end-use combustion of natural gas and heating oil and

efforts to mitigate the electricity grid peak impacts that result from electrifying those end uses (e.g., via energy efficiency, demand response, etc.). Efforts in the building sector can also reduce industrial emissions by advancing the phase-out of high global warming potential refrigerants and planning new construction to minimize the embodied carbon of construction materials. There are two critical strategies to achieve this transformation: replace fossil fuel end uses in buildings with net-zero energy and improve building efficiency.

Replace fossil fuel end uses in buildings with net-zero energy

Natural gas and oil supplied about half of residential energy requirements in 2022 (46% and 3%, respectively), and a little more in the commercial and institutional sector (51% and 2%).[327] Most is used for space and water heating, although some goes for appliances (cooling systems, stoves, dryers) and backup power systems. Net-zero energy options for the future mainly run through electricity, but other niches might be supplied through biofuels or even hydrogen.[329]

Electrification as the primary pathway

Electricity is typically the most straightforward alternative for building energy needs. It already supplies about 44% of commercial, institutional, and residential building energy use and is widely used for both space and water heating. Although electric heating has traditionally taken the form of resistance devices (baseboard heaters or furnaces), ground or air source heat pumps can dramatically reduce electricity requirements and fuel cost.

Heat pumps use refrigerants to transfer outside heat into a building for heating in the winter and reverse this process for cooling in the summer. They can be several times more efficient than electric resistance. But this is not always sufficient to enable them to

compete successfully with gas appliances, given their higher upfront costs, especially for ground source heat pumps.[338]

The cost-competitiveness of heat pumps depends on several factors, including local electricity and natural gas prices, and climate conditions.[339] As demand for electric heating rises, concerns also grow around ensuring adequate electrical capacity and access to low-cost, clean power.

Heat pump performance has improved in both standard and cold-climate models to the point that replacing electric resistance heating, oil, or natural gas furnaces can deliver substantial cost savings over time in most provinces. In colder regions or where electrical capacity is limited, dual-fuel systems offer a practical transition by pairing a heat pump with a natural gas, propane or fuel oil furnace for backup. One analysis shows that using a heat pump in place of a central air conditioner while retaining existing heating as backup results in cost savings across every province. Overall, heat pumps are now the lowest-cost heating option for a majority of Canadian households.[339,340]

Heat pump uptake has risen in Canadian residential buildings over the last 20 years (see Figure 27). Heat pumps now provide 3.5% of the residential space heating energy mix. [341] Commercial uptake of heat pumps is not substantial to date.

Supplementary low-carbon energy sources

Buildings can also generate their own electricity. Rooftop solar panels are already a familiar sight in Canadian cities. When combined with passive energy design elements and building envelope improvements that reduce heating requirements, these technologies may be able to displace a large fraction of the annual electricity load for many buildings. This could relieve pressure for electrical grid expansions.[342]

Biomass currently supplies about 5.5% of residential building energy needs, mainly in the form of wood or wood pellets.[327] Biomass is typically considered carbon neutral, but the actual emission footprint includes greenhouse gases such as nitrogen oxides, as well as sulphur dioxide and soot. [343] Biomass also has fossil inputs

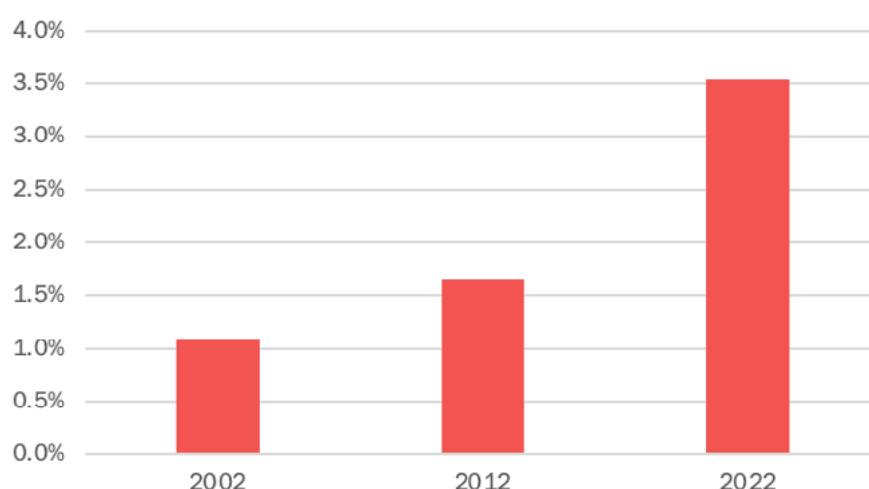


Figure 27. Heat pump share of residential space heating, Canada 2002, 2012, and 2022

associated with harvesting, processing and transport. Improved practices could significantly reduce these emissions, but biomass is unlikely to become a major source of building heat because of concerns over air quality, scalability, logistics and alternative feedstock demand.

Another option is to exploit the existing natural gas distribution network, but substitute a net-zero gaseous fuel. This could be “renewable natural gas” made by anaerobic digestion of organic wastes or eventually “synthetic natural gas” made by using low-carbon feedstocks and electricity.

Problems with renewable natural gas include cost, residual emissions, and scalability. Although the carbon dioxide generated when renewable natural gas is burned is considered part of the natural carbon cycle, methane leaks across the supply chain could be significant. Marginal emissions reductions are achieved today by blending renewable natural gas with conventional natural gas, but opportunities to extend this approach are limited. Torchlight Bioresources estimates that the feasible renewable natural gas supply from all feedstocks could only generate up to 3.3% of Canada's 2029 natural gas consumption.[344] On the other hand, synthetic natural gas is far from ready for market and would require significant low-carbon electricity that may be better used for direct electrification.

Finally, hydrogen could be distributed through a modernized gas grid and used as a form of stored energy. This would require investments in low-carbon hydrogen production and replacement or upgrading of gas transmission and distribution networks, meters and end-use appliances.[345] Additional challenges include increased fire and explosion risks from hydrogen[346] and projected high costs for delivered

low-carbon hydrogen. A meta-analysis of 54 studies from around the world concluded that hydrogen was not generally a cost-effective pathway to building decarbonization.[347] Hydrogen fuel cells could contribute to the management of building electrical supply (serving as storage for building-integrated renewable generation) or for back-up power. The deployment of a hydrogen building heating option at scale could be made more viable in specific regions by demand development in other sectors (heavy freight, industrial users, and so on).[348] However, it is not expected that hydrogen will play a significant role to heat buildings in Canada, especially in provinces where electrification could supply heating at scale. Further details on these alternative low carbon fuels can be found in chapter 7.3.

Improve building energy efficiency

A critical supporting element for building decarbonization is the promotion of energy efficiency, which can reduce demand pressure on the supply system and keep costs down for consumers. Energy efficiency measures can lower building heating loads, reduce demand on the electricity grid for new generation or transmission, help control electricity costs and reduce the price differential with gas. [349,350] New buildings can be built to higher energy performance standards using:

- Improved building envelopes (better insulation and air sealing),
- Passive design principles,
- Energy-efficient HVAC and lighting systems,
- Smart controls, and
- New materials (low-carbon cement or steel).

Retrofits are important for older structures, particularly for the large stock of buildings with poor energy efficiency built before 1960.[351] Better windows, doors, exterior siding and caulking, additional insulation, and improved envelope air sealing and roof structures can all significantly lower energy requirements, particularly when coupled with energy-efficient equipment.[351] This will have the greatest energy, emissions, and cost impacts when applied to older buildings.[352] Nevertheless, building envelope retrofits can be very expensive and disruptive with long payback times, and should be synchronized with the building lifecycle where possible.

These two foundational elements—replacing fossil fuel end uses and dramatically raising building energy efficiency—form the foundation for transition pathways in this sector and can be pursued in an integrated manner in new builds and retrofits of the existing building stock.

Cross-cutting and long-term system changes

Additional elements which connect buildings to wider systems, such as electricity, industry, transport, and community design, include:

- Grid expansion and decarbonization, ensuring that increased electricity demand from buildings is met with clean power (discussed in chapter 7.1).

- Replacement of high-global-warming-potential refrigerants used in building cooling systems and heat pumps with climate-benign refrigerants and technologies.
- Transition to net-zero-emission building construction by decarbonizing steel and concrete production, using low-carbon alternatives like engineered wood, and eliminating emissions from construction, manufacturing, and transport.
- Management of construction and demolition waste streams to reduce landfill use and material-related emissions.
- Promotion of sustainable urban design to enhance well-being while encouraging climate-friendly patterns of living. Changes here could include:
 - » Mixed-use community design with district energy schemes,
 - » Urban densification with accessible mass transit and lower energy demand than suburban housing, and
 - » Shared green spaces and local work hubs that may encourage a trend towards smaller homes or teleworking.

Competitiveness Implications

Canada needs to retrofit over 6.5 million homes built before 1984, yet the Greener Homes Grant delivered only 29,000 deep retrofits over five years. That gap reflects a market-formation problem more than a technology one. The retrofit industry remains fragmented across small firms and independent contractors, without a standardized project pipeline large enough to attract sustained private capital or support workforce specialization. This decade's equipment replacement cycle, the last full cycle before 2050 given 15-to-25-year system lifespans, is the window that determines whether Canada industrializes cold-climate retrofit delivery or enters the 2030s still treating deep retrofits as bespoke projects. If replacement decisions continue to default to gas and procurement remains fragmented, the volume needed to drive cost reduction and workforce formation will not materialize. Jurisdictions that industrialize during this window will set the terms for a market that late movers enter at a disadvantage.



9.1.4 Priorities for Action

Achieving a net-zero building sector requires action on four fronts: raising standards for new construction; electrifying, retrofitting, and decarbonizing existing buildings; mandating stronger performance standards; and building the financing and innovation capacity to deliver change at scale.

Raise standards for new construction

Each new structure built without low-carbon standards locks in years of greenhouse gas emissions, making decarbonizing new construction an urgent priority.[335] A central goal is the universal adoption of Canada's Net-Zero Energy Ready Code, with continued support to accelerate progress beyond minimum requirements. Recent updates to national model building codes, introducing operational GHG emissions limits alongside enhanced energy efficiency requirements, are already raising the bar for new residential, commercial, and institutional buildings.[353] Natural gas phase-outs for new buildings, already underway in some jurisdictions, should be more broadly considered. Eventually, building standards should evolve to address embodied carbon by promoting low-carbon material choices and reducing emissions from construction, manufacturing, and transportation.

Building codes should preserve flexibility in heating, cooling, and envelope design strategies while progressively escalating toward net-zero emission standards. In the residential sector, higher standards must be carefully coupled with industry support to avoid compounding affordability concerns.

Accelerate electrification, low-carbon energy, and retrofits in existing buildings

Because most of the 2050 building stock already exists, and heating equipment is replaced only periodically, electrification and

retrofit efforts need to accelerate now to avoid locking in fossil fuel use for decades.

For existing buildings, electrification and fuel switching should be the priority. A simple near-term strategy is to ensure that all newly installed cooling systems are heat pumps with heating capability, normalizing the technology while building workforce capacity in installation and servicing. Dedicated efforts may be required to ensure the switch is economically attractive to building owners through incentives, regulations, and public education. Although heat pumps can already be cheaper to operate than natural gas or oil-based heating, high upfront capital costs and ongoing concerns about electricity prices remain barriers to adoption. Programs should ensure that clean alternative technologies become more attractive than those powered by natural gas. Transitioning to low-GWP refrigerants in heating and cooling equipment should also accompany the broader shift to heat pumps.

District heating can be an efficient and cost-effective way to heat buildings by distributing heat from centralized sources (waste heat from industry, data centres, and sewers) to clusters of buildings. Coordinated planning among the private sector, utilities, and multiple levels of government is crucial for scaling these systems. Enabling these projects can require changes to utility rate structures, zoning, and urban planning.

Efforts to scale up energy efficiency retrofits should focus on older buildings where energy, emissions, and cost savings are greatest. These retrofits can be pursued independently of electrification or fuel switching but yield greater benefits when combined. Key enablers for the retrofit ecosystem are investing in skilled labour training and stimulating consumer demand. Expanding training and professional certifications in integrated design principles and heat pump installation

will support the workforce needed for wide-scale deployment of clean heating technologies. At the same time, as the transition proceeds, natural gas infrastructure risks becoming stranded assets with costs that can disproportionately affect lower-income households—reinforcing the importance of making retrofit pathways accessible and affordable.

Mandate performance standards and labelling

Mandatory building emissions performance standards and labelling can help buyers or tenants choose better-performing spaces with lower operating costs and encourage existing building owners to invest in fuel-switching technologies and energy efficiency measures. Standards should be augmented with minimum emission performance requirements that increase over time and systematically target the worst-performing buildings. To be successful, energy and emissions disclosure must be mandatory at the point of sale, rent, or lease for both commercial and residential buildings. Regular updating and harmonizing of minimum performance standards for appliances and equipment will ensure that low-carbon options are chosen during construction and retrofits.

Build financing capacity and drive innovation

A core objective is to create institutional structures for a functioning private market for fuel switching and building retrofits. This requires developing common underwriting standards, aggregating small retrofit projects into larger financial portfolios, and demonstrating investment opportunities to the private sector through de-risking, co-investing, and information sharing. A publicly supported investment vehicle can accelerate this process. Public sector procurement across all levels of government can also drive demand for net-zero new builds and retrofits.

Targeted R&D and market development can support emerging technologies, including cold-climate heat pumps, prefabricated wall assemblies, digital tools for virtual energy audits and building energy management systems, and hydrogen heating, where regionally viable.

Together, these strategies can establish a foundation for a net-zero building sector that is efficient, affordable, and equitable.



 Fails to meet criteria Meets in some respect
 Not promising Potentially meets criteria
 Meets criteria

ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
	ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
Net zero with a decarbonized electrical grid.	Cost competitiveness varies by region and building type. Residential single units most often achieve parity, but economics weaken for multi-unit and commercial buildings, in cold climates, and where gas is cheap.	Some potential for domestic assembly, installation, and distribution jobs. Manufacturing is typically international.	Commercially mature for residential applications across Canada. Well-established and growing for commercial and institutional buildings.	Used across Canada in buildings. Less efficient in very low temperatures.	Upgrades to grid and generation may be needed to accommodate increased demand.	No particular concern.	Increasing interest from utilities and HVAC companies as the need to decarbonize becomes clearer. Interest from some building owners in terms of savings. Some hesitancy from contractors to recommend newer technologies, preferring to stick with incumbents.	Reduced grid demand compared to other electric alternatives. Some concerns with emissions from refrigerants.
Net zero with a decarbonized electrical grid.	Installation significantly more expensive than ASHP but efficiency and operational savings are greater. Payback periods lengthy.	Some potential for domestic assembly, drilling, installation, and distribution jobs. Manufacturing is typically international.	Mature for residential, and commercially available for commercial and institutional buildings.	Site suitability is a constraint; not all buildings have suitable land area or soil conditions. More efficient than ASHP overall and in cold climates specifically.	Upgrades to grid and generation may be needed to accommodate increased demand. Specialized drilling equipment may not be available in remote/rural areas. Community and district applications face gaps in standards.	No particular concern.	Growing interest from institutional building owners, developers, and utilities for large scale and district projects. Limited residential interest and more niche than air source heat pumps. Some hesitancy from contractors to recommend newer technologies, favouring to stick with incumbents.	Reduced grid demand compared to other electric alternatives. Some concerns with emissions from refrigerants.

PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
				ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
Dual Fuel (Hybrid) Heat Pump Systems (Heat pump & natural gas or fuel oil furnace as a back-up)	Bridge Pathway Applicable until clean electricity is widely affordable, available, and reliable.	Deploy Support deployment where electricity is expensive or climates are very cold through education, incentives, building codes, and subsidies that assist with capital costs. Provide workforce upskilling.	 Significant GHG reductions but still some GHGs associated with fossil fuel combustion.	 Similar economics to ASHP. Can be cost competitive in some regions.	 Some potential for domestic assembly, installation, and distribution jobs. Manufacturing is typically international.	 Mature for residential, and commercially available for commercial and institutional buildings.	 Used across Canada in buildings. Dual fuel can compensate when temperatures are very low.	 Requires electricity and incumbent heating source (i.e. natural gas, fuel oil), which are available in almost all locations in Canada.	 Well accepted. Viewed positively in terms of cost savings.	 Increasing interest from utilities as need to decarbonize becomes clearer. Interest from building owners in terms of savings. Some hesitancy from contractors to recommend newer technologies, favouring to stick with incumbents.	 Reduced grid demand compared to other electric alternatives. Some concerns with emissions from refrigerants.
Dual Fuel (Hybrid) Heat Pump Systems (Heat pump & renewable natural gas or hydrogen furnace as a back-up)	Potential Niche Pathway Applicable where clean electricity access is limited, clean fuels are accessible, and where a back-up furnace may be required (i.e. extreme cold or remote regions)	Incubate Support development of hydrogen and RNG supply chains as well as R&D projects using clean fuels as heat pump back-ups.	 Significant GHG reductions but may require removals. Can be net-zero with sustainable feedstocks.	 Worse economics than dual fuel with fossil fuels as clean fuels carry premiums. Hydrogen furnaces have very high capital costs.	 Some potential for domestic assembly, installation, and distribution jobs. Manufacturing is typically international. Can support RNG and hydrogen production.	 RNG is a drop-in fuel and mature, with some utilities offering purchase. Hydrogen furnaces have lower maturity in early-stage demonstration.	 RNG is a drop-in fuel and requires no modifications. Hydrogen requires replacement of existing furnace and appliances.	 Requires RNG or hydrogen, which have limited supply and require substantial infrastructure build out to connect generation to broader consumption. Additionally, electricity is needed.	 Well accepted. Viewed positively in terms of cost savings. Some concerns around safety of hydrogen.	 Some interest from utilities as need to decarbonize becomes clearer. Some hesitancy from contractors to recommend newer technologies, preferring to stick with incumbents.	 Reduced grid demand compared to other electric alternatives. Some concerns with emissions from refrigerants. RNG has indoor air quality concerns.
Baseboard or Electric Furnace	Niche Pathway Relevant for some buildings where heat pumps are not practical.	Deploy Support in contexts where heat pumps are not viable (i.e. as a back-up to heat pumps and/or in very cold regions).	 Net zero with a decarbonized electrical grid.	 More expensive in regions with low-cost natural gas, but widely used.	 Already a mature industry, supports existing jobs.	 Commercially mature.	 Used across Canada in buildings.	 Requires upgrades to the electrical grid and generation to accommodate new demand.	 Widely accepted and used in many households across Canada.	 Established market alternative.	 Very low overall environmental impact. High electricity demand, inefficient compared to heat pumps.

PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
				ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
Hydrogen in Place of Natural Gas	<i>Potential Niche Pathway</i> Could be relevant in specific geographies where the availability and price of net-zero hydrogen are positive.	Don't Prioritize Support if niches emerge in locations with substantial hydrogen infrastructure buildout.	 Can eliminate heating emissions if hydrogen is net zero. Some concerns around hydrogen leakage and associated GHGs.	 Potential for high costs for net-zero hydrogen. Viability is location specific.	 Domestic potential to produce net-zero hydrogen and build up a surrounding industry.	 Low blends currently piloted in some locations in Canada.	 New appliances and modified furnaces are required.	 Gas infrastructure requires substantial upgrading. Supply of net-zero hydrogen as an energy source is currently very limited.	 Concerns around safety may cause mixed views in communities.	 Limited interest. Some relevance from existing natural gas producers and utilities to continue use of gas networks.	 Some concerns around safety due to leakage and high flammability. Substantially reduces indoor air quality concerns.
Natural Gas	Dead-End Pathway GHG emissions occur at point of use, cannot achieve net zero.	Dismiss Phase out use of natural gas in buildings using building codes and other policy instruments.	 Produces emissions during combustion, transport, and production. Methane leakage remains a concern.	 Low cost compared to other heating alternatives.	 Already a mature industry, supports existing jobs.	 Commercially Mature.	 Used currently across Canada in many locations and types of equipment.	 Incumbent technology in many locations. Some regions are difficult to reach with pipelines.	 Generally, widely accepted and used in many households across Canada.	 Important to industry and utilities.	 Increasing concern with indoor air quality issues.
Renewable Natural Gas	<i>Niche Pathway</i> Applies in specific contexts such as a facility or community. Not applicable at large scale given limited feedstock.	Don't Prioritize Support development of feedstock including biogas capture and biomethane in appropriate contexts.	 Only net zero if RNG fully displaces fossil natural gas. Requires low-carbon feedstocks. Methane leakage remains a concern.	 Costs vary by geography and can be very high depending on availability of feedstocks.	 Some local opportunities especially for waste or organics management facilities.	 Some small-scale or local deployment and use. Not used frequently for building heat beyond blending with conventional NG.	 As a drop-in fuel for natural gas.	 Uses incumbent technology. Can be difficult to connect some RNG suppliers to the existing NG network.	 Should receive the same level of acceptance as conventional NG.	 Interest and some investment in various regions in Canada from utilities and feedstock suppliers.	 Increasing concern with indoor air quality issues. Waste valorization.
Synthetic Natural Gas	<i>Potential Dead-End Pathway</i> Supply cannot meet demand with current maturity and costs. Prolongs use of dead-end assets.	Dismiss Economics and maturity limit viability.	 Net zero in principle but requires net-zero hydrogen and biomass or direct air capture. Methane leakage remains a concern.	 Very high cost. Depends on reliable and low-cost supply of net-zero feedstocks or offtake of carbon.	 Limited by feedstock or carbon storage availability.	 In early research phase.	 Is a drop-in fuel for NG which is used currently across Canada in many locations and types of equipment.	 Uses incumbent infrastructure. Can be difficult to connect supply to NG network. Major buildout of feedstock supply chains required.	 Likely to be socially acceptable.	 Still in research, so not relevant to many stakeholders at this time.	 Indoor air quality issues. Methane leakage during transport and production.

PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
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Biomass Combustion	Niche Pathway Could be used in remote locations where electricity isn't available, in district energy systems, and/or as a back-up heating system.	Don't Prioritize Relevant where other options are not applicable.	 Can be net-zero when feedstocks are decarbonized.	 Viability depends on location.	 Largely developed. Potential for local economic development in remote or Indigenous communities.	 Commercially mature.	 Used mainly in residential buildings in some areas of Canada.	 Supply chains exist today but are unlikely to scale. Difficult logistics in moving feedstocks.	 Some concerns about indoor air quality but widely accepted and used in many residences.	 Unlikely to expand beyond current measures.	 Can use forestry residues. Air quality and health concerns.
 Building Design and Energy Systems											
Net-Zero Design for New Builds	Priority Enabling Pathway Buildings need to be built so that they will not require future net-zero retrofits.	Deploy Implement and accelerate net-zero building codes now at the municipal, provincial, and federal level. Support training programs to certify the workforce.	 Net zero with a decarbonized electrical grid. Further decarbonization can be achieved when low-carbon materials are used for building.	 Upfront costs may be higher. Can be cost competitive over the lifecycle of a building.	 Large opportunity for job creation. Housing deficit and building for climate resilience provide opportunity for net-zero building industry to grow. Anchor tenant for low-carbon building materials.	 Emerging industry. Some buildings exist in Canada.	 Requires training for builders to learn new codes and technologies.	 Relies on access to or production of clean electricity and heat pump technologies. Infrastructure and maturing supply chains are available in most locations.	 Viewed positively as it can improve air quality, comfort, noise, lighting and operational costs. Some wariness around efficacy and upfront cost.	 Some builders are adopting practice as a competitive advantage. Wariness around upfront cost premium.	 Improvements to health and comfort of people living or using the buildings. Air quality improves.
Retrofitting for Existing Builds	Priority Enabling Pathway Retrofits are required to reduce emissions from the current building stock.	Deploy Support retrofits with financing mechanisms, especially where affordability is a concern or deep retrofits are required. Provide consumer education. Support training programs to certify the workforce.	 Net zero with a decarbonized electrical grid. Further decarbonization can be achieved when low-carbon materials are used for building.	 Many investments pay for themselves through energy savings over time. Deep retrofits are more challenging.	 Large opportunity for job creation. Housing deficit and building for climate resilience provide ample opportunity for net-zero buildings industry to grow.	 Building technologies relatively mature but finance mechanisms and approaches to mass retrofits are still emerging.	 Requires builders to learn new codes. Installation of newer technologies requires training. Deep retrofits can cause significant disruption to building operations and are best timed with lifecycle of assets.	 Relies on access to or production of clean electricity and heat pump technologies. Infrastructure and maturing supply chains are available in most locations.	 Viewed positively as it can improve air quality, comfort, noise, lighting, and operational costs. Some wariness around efficacy and upfront cost.	 Undervalued by building owners who rent or lease, especially where tenants pay utilities.	 Improvements to health, air quality, and comfort of people living in or using buildings.

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District Energy Systems (Powered by Net-Zero Energy)	Enabling Pathway Reuses waste heat and can reduce costs for building heating where applicable.	Deploy Support buildout where waste heat is available and buildings are clustered.	 Aligned if powered by net-zero energy. Emissions reductions from increased efficiency but only applicable where buildings are clustered.	 High upfront cost but return on investment occurs from reduced energy costs.	 Municipalities or private companies will have major design and installation work.	 Commercially mature. Limited deployment currently.	 Can be integrated into buildings and communities at design stage. More challenging to retrofit existing urban infrastructure.	 New infrastructure required. Challenging for planning systems, coordination of multiple owners and stakeholders. Project execution and management difficult.	 Viewed positively for new builds but may be some controversy with retrofits.	 Some relevance to gas utilities as an alternative business model as decarbonization proceeds.	 Reduces air pollution and burden on the energy system.
Solar Panels on Buildings	Enabling Pathway Relevant to regions and buildings with good sun exposure.	Deploy Deploy financing mechanisms for developers and building owners. Provide workforce training for installation. Pilot programs to integrate micro-generation with the larger electricity grid, working collaboratively with utilities.	 Can be part of net-zero buildings (assuming panel lifecycle emissions are managed).	 Costs have declined dramatically over time. Economics can depend on regional incentives. Return on investment occurs over solar panel lifespan.	 Industry is well established. Some opportunities for local installers.	 Commercially mature.	 Power output likely not high enough to meet all needs in conventional buildings.	 Supply chain is mature.	 Widely accepted and non-disruptive. Some pushback over aesthetics.	 Some interest from building firms and owners. Recognized in federal net-zero strategy for transforming Canada's buildings.	 When paired with storage, provides resilience in power outages and reduces daily peak demand. Can sell energy back to the grid. Issues with disposal and differing lifespan from building materials.
Building-Integrated Solar PV	Enabling Pathway Relevant to regions and buildings with good sun exposure.	Deploy Technologies and materials maturing. Support further development of materials, approaches, standards, and demonstration.	 Can be part of net-zero buildings (assuming material lifecycle emissions are managed).	 Costs have declined dramatically over time. Economics can depend on regional incentives. Return on investment occurs over solar panel lifespan.	 Industry still emerging. Opportunities for materials and construction will expand with maturity.	 Commercially available with demonstrated projects in Canada. Not a mainstream solution.	 Requires retrofit (new roofs, facades, windows etc.). Better suited for new build construction. Must be integrated into building design codes.	 Supply chain is emerging.	 Widely accepted and non-disruptive.	 Niche interest among innovation-focused stakeholders, with limited utility impact due to small scale.	 When paired with storage, provides resilience in power outages and reduces peak demand. Can sell energy back to the grid. Immaturity of recycling panels and differing lifespan from building materials.