Changing course: a strategic approach to get Canada to net-zero

INSTITUT DE L'ÉNERGIE TROTTIER

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About the Trottier Energy Institute (IET)

The Institut de l'énergie Trottier (IET) was created in 2013 thanks to an exceptional donation from the Trottier Family Foundation to Polytechnique Montréal. Since then, it has been involved in every energy debate in the country. At the source of major collective reflections, the team mobilizes knowledge, analyzes data, popularizes issues and recommends fair and effective plans, simultaneously contributing to academic research and training. Its independence gives it the neutrality essential to the collaborative approach it advocates, facilitating work with the players most likely to advance the energy transition, while allowing it to be freely critical when relevant. As the initial 10-year mandate came to an end, the Trottier Family Foundation decided to renew its confidence in the IET and made a new donation. Given the scope of the IET's activities and its status as a key player, its mandate was extended. The team will thus be able to continue offering science-based advice and enriching societal dialogue in order to advance the way we produce, convert, distribute and use energy.

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Executive summary

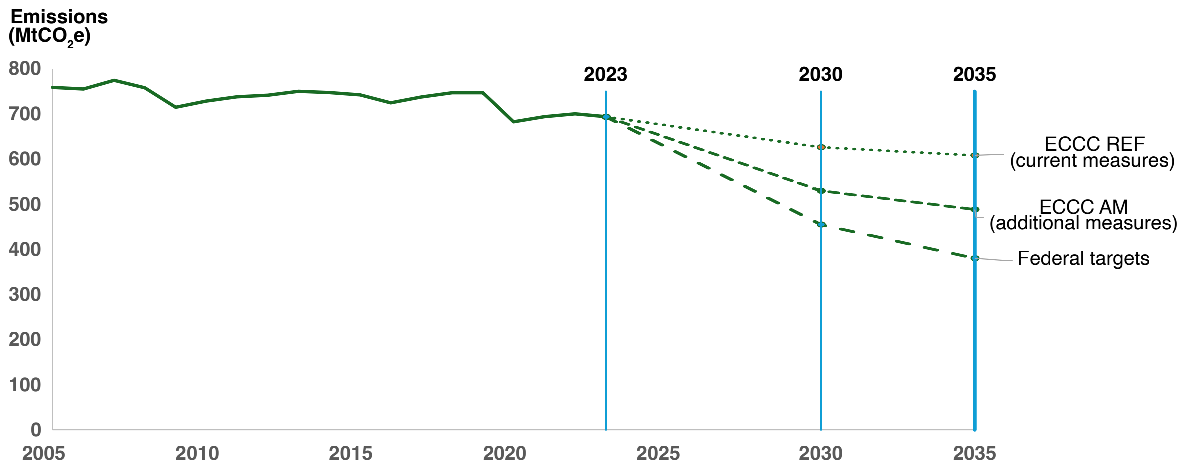
At present Canada is not on track to reach net-zero GHG emissions by mid-century.

Despite the climate policies introduced by the federal government since 2015, and optimistic assessments of Canada's 2022 Emissions Reduction Plan, a recent report from Environment and Climate Change Canada (ECCC) recognized a substantial gap remains between reductions anticipated from existing climate policies and the official 2030 and 2035 interim targets (Canada, 2025). This is consistent with the earlier assessment in the Institut de l'énergie Trottier's Canadian Energy Outlook (Langlois-Bertrand *et al.*, 2024). ECCC now forecasts an 18% GHG reduction rather than 40% for 2030, and 20% rather than the intended 50% for 2035 (Figure ES1), a projection that does not include the impact of the repeal of the consumer-facing carbon levy. According to ECCC, the adoption and full implementation of all other measures being considered by government (so called 'advanced measures') could partially close this gap by achieving a 30% GHG reduction by 2030 and 35% by 2035.

Without further significant action the country would therefore achieve less than half the targeted reductions. Considering the difficult political conjuncture, with turmoil over tariffs, the hostility of the current US administration to the energy transition and international climate regime (as well as the Canadian government's poor record of accurately anticipating future emissions trajectories), even these results are far from certain. In the meantime, many of Canada's OECD counterparts have managed to make greater progress. In contrast to Canada, European countries have decreased their emissions significantly since 1990. So, while every country faces its own unique challenges and conditions, a large number of states have succeeded in deploying strategies that allow sizeable reductions in emissions, compatible with the Paris Agreement objectives.

This failure is not only environmental: we are not moving rapidly enough to build the new economy that will be required for Canadian prosperity in the second half of the century.

Figure ES1 - Historical and projected GHG emissions according to different scenarios



Source: Canada (2025)
Note: the measures included in the current measures (REF) and additional measures (AM) scenarios are detailed in Canada (2024)

Many factors have contributed to limiting progress :

1. It was always going to be difficult to curtail emissions in a country with a resource-based economy, expanding oil and gas exports, widely varying regional energy political economies, decentralized political arrangements, and close economic integration with the United States.
2. Moreover, the interim (2030) abatement target adopted by the federal government in 2021 was not based on careful bottom-up analysis but on political expediency.
3. Despite its name, the **Emissions Reduction Plan was not a workable plan** that identified the concrete requirements for reducing emissions and then established gradual steps to achieve these. Rather it was an aspirational modelling exercise tweaked to show the desired outcome.
4. Policy development was excruciatingly slow (not aided by excessively complex pricing and compliance mechanisms that lacked transparency), and large amounts of political capital were wasted on initiatives that can contribute little to transitioning Canada's systems to net zero.

In this report we reexamine the challenge of decarbonizing Canada's economy by mid-century, consider the progress that has been made to date, and outline measures that can reorient efforts to make progress in key economic sectors. Before presenting our detailed analysis, it is beneficial to lay out our approach.

Adopting a more strategic stance

To decarbonize our economy over the next 25 years, the 'gap' between ambition and practical actions must be closed. This means adopting a more strategic approach that includes:

1. Shifting focus. Instead of worrying about short-term emission reduction targets we should **prioritize real-world changes that gradually transform our systems**, so emissions are essentially eliminated by mid-century. Tracking physical indicators (the installation of clean electricity generation, the number of buildings converted to electric heating) and measures of market transformation (percentage of EVs in total auto sales, relative costs of gas and electric heating) in these systems is more important than tabulating annual emissions reductions.
2. Recognizing that **climate policy is increasingly linked to economic development and industrial policy**. Renewable technologies (solar, EVs) are now being adopted by poorer countries to accelerate economic development, and nations are jostling to secure their place in low carbon production chains. For Canada net zero is about building an economy that can be competitive and prosper in a decarbonizing world. Support for clean electricity buildout, value-added transformation of natural resources (mining and processing critical minerals) and manufacture of low-carbon technologies (EVs, heat pumps, electrical system components, etc.), creates the foundation of future affluence, gives us tools to decarbonize our domestic economy, and can strengthen political coalitions favouring more vigorous action.
3. **Embracing asymmetrical decarbonization.** Sectors, provinces and regions will proceed down pathways, and at rates appropriate to their circumstances. Policies should be adapted to the phase of transition in different regions and sectors. Where solutions are ready, policy measures should accelerate mass deployment. Where solutions are not yet clear, policy can support R&D, experimentation, and measures to prepare eventual market transformation.
4. **Adopting a planning and implementation mind set:**
   - **a)** *Think first about what a net zero economy would look like*. How do we organize effective systems for moving goods, heating buildings, providing electricity, and so on, that do not result in net GHG emissions? Of course we cannot anticipate every detail. But we already know the basic structure of a net zero energy system.
   - **b)** Then ask *what sequence of changes in the physical world* is required to achieve this goal. This includes the buildout of infrastructure (power plants and EV charging stations), the adoption of new end-use technologies (EVs on the roads, heat pumps in buildings), and the development and eventual adoption of novel technologies (for heavy industry, net zero aviation, carbon removals, and so on).
   - **c)** *Examine the barriers to and enablers* of the desired transformation in each specific context (the sector, province or city) and adopt appropriate policy measures to secure the physical changes that construct the future economy. By working backwards from the desired system architecture, it is possible to plan the concrete steps required to build the new economy.
   - **d)** *Monitor progress*, through relevant indicators, and adapt to what is happening on the ground on an almost continuous basis.

5. **Supporting the new rather than punishing the old.** Society will not primarily abandon fossil fuel resources because supply has been politically constrained but because demand has been eroded by superior renewable technologies and electric end-uses with higher performance, that are convenient, safer, and ultimately cheaper. So the policy emphasis should be on rolling out the new, with a strategy to drive costs and prices down while demonstrating the benefits of new technologies, rather than penalizing the old. As fossil fuel dependence is eroded on the demand side, the balance of forces between old and new energy systems, and the political calculus, will change and the transition can accelerate. But targeting fossil energy producers directly (when oil remains the country's largest export earner and several province's economies are based on the petroleum industry) is politically challenging.
6. **Paying attention to prices.** In the short term, prices are largely given, but over time they are influenced by investment. Learning rates (the price fall with doubling of deployment), economies of scale and regulations can dramatically transform relative costs. Thus, the purchase price of solar panels has dropped by 90% over the past decade. Policy can help drive down the price of new technologies by encouraging uptake through procurement, training, strategic production or consumption subsidies, regulations and other mechanisms. Carbon pricing acts in the other direction, by raising the costs for fossil fuel-based options. But, as we have seen, measures that raise prices are likely to meet political resistance, and people resent an imposed loss (for example, through taxes) more than an advantage conferred to others (for example, through subsidies). More generally in navigating the energy transition governments must take care to avoid a sudden rise in energy prices (for example electricity rates), or concentrated losses imposed on a particular industry, occupational group or region, for they can spark a backlash that can derail plans for years. They must also ensure that policies drive structural changes that lower the price of the desired technologies and services.

Reaching net-zero: how to achieve transformative outcomes

As we show in this report, what all this means in sectoral terms is:

For electricity:

- Steadily and rapidly expand non-emitting grids (especially wind and solar generation, storage and transmission) to meet the growing need for electricity as other sectors (transport, building heating, industry) decarbonize
- Gradually phase out any remaining coal-fired generation and unmitigated gas generation
- Implement strategies to mitigate the short and medium-term challenges of rapid electrification in different grids across the country, for instance seasonal peak exacerbation as well as distribution- and transmission-level short-term capacity constraints

For transport:

- Accelerate the uptake of light and medium duty electric vehicles
- Continue R&D and experimentation with heavy-duty road vehicles (and off-road vehicles), with battery electric and hydrogen fuels cells as the most promising options
- Build out high-speed rail in major inter-city transport corridors and extend electrified public transit systems
- Continue R&D and experimentation with net zero options for rail, marine and aviation

For buildings:

- Stop building new residential and commercial structures with gas-fired heating
- Systematically retrofit existing buildings with low carbon heating systems (mainly with air source heat pumps, but in some circumstances other net-zero options may be practical).
- Encourage energy efficiency improvements for new and old buildings to reduce clean energy supplies that will be required in a net zero world.

For industry:

- Electrify mechanical operations and low-temperature heat in industry
- Gradually convert high-temperature heat provision to electricity, hydrogen or biofuels
- Progressively address process emissions, timing lumpy investment with cycles of capital renewal

For oil and gas:

- Ensure industry lowers production emissions with the goal of achieving net zero for the sector by mid-century. How quickly emissions can be brought down depends on political decisions and the speed with which the Canadian and global economy decarbonizes.

But these goals can only be met by implementing the general principles underpinning the strategic approach outlined above. To inform this discussion, we propose a closer look at sectors to illustrate what this might look like.

Designing a strategic approach

Developing a strategic approach to meet these components of a prosperous net-zero Canada requires a focus on structural transformations that can enable the realization of these goals. It also requires seizing on the considerable opportunities to enhance productivity and the competitiveness of Canada's economy through these transformations.

To illustrate how this can be achieved, in Section 3 of the report we focus on three sectors and propose an assessment of needs and a strategy to address them: buildings, road transport, and industry. We also provide an overview of the challenges facing other sectors, to be analysed in more detail in a subsequent report. Our proposed sector strategies aim to transform markets and reduce prices, thereby facilitating and accelerating the transition to low-emission services. In so doing, each strategy follows similar principles for approaching the design and implementation of decarbonization measures.

The framework covers:

1. *What net-zero transformation looks like:* what are **the key elements of an improved system** that can provide services in the sector and that does not result in net GHG emissions?
2. *Which physical changes are needed to get there:* what are the **essential material components** required to achieve such a system transformation, and at what pace?
3. *How to overcome key barriers:* what are the **foreseeable obstacles** that must be removed, in as many relevant locations around the country as possible, to facilitate the necessary changes? What measures (coordination efforts among key stakeholders, regulations, policies, etc.) can be enablers to support the deployment of the transformative pathway?
4. *Capturing economic benefits:* **what strategic economic interests** for Canada can be realized through the successful deployment of the strategy?

Each strategy is then summarized in a table with the main objectives and action items for the short term (a year), medium term (1-5 years) and longer term (5-25) years.

NOTE

For this report, we accept the government's 2035 targets (with the sectoral split consistent with the 2030 additional measures modelling run) as a reference point for discussion and to highlight the gap between stated ambition and anticipated system transformation (and emissions reduction) over the coming decade. This does not necessarily imply that we believe the 2030 or 2035 targets were well chosen, or that the sectoral contributions to emission reduction should be those implied in the 'additional measures' scenario, or indeed that these contributions will remain constant over time. Indeed, everything we know about market transformation suggests the process is not linear, but takes place slowly at first, then accelerates, and then slows again. And these changes will not be aligned across different across sectors and regions, so their relative contribution to emission reductions will vary at different points in time.

The real goal here is an essentially decarbonized economy by mid-century. And this will require transformative measures along the lines discussed in the sections below over the next 20-30 years. Whether one thinks that the target for a particular sector is too stringent or not sufficiently stringent; and whether a specified degree of market transformation is achieved in 2031, 2035, or 2039, the same general sequence of changes discussed below, and reductions on something like the same scale, will be required for any feasible plan to reach net zero by mid-century. If change is to be slower in earlier years, then it will have to be more rapid in subsequent periods as technologies mature, prices fall, and infrastructure is built up. So the basic steps outlined in the sectoral strategies below remain the same whether we dig in our heels next year or continue to defer action. Of course, the window for Canada to seize opportunities in international net-zero supply chains may close as other countries pursue more vigorous action.

With this set of measures in mind, we build a tentative timeline for these transformations (Figure ES2).

Figure ES2 - Timeline of high-level elements in national strategy

Objectives	2025	2030	2035	2040	2045	2050
No gas installed in new residential and commercial buildings	Deploy		Complete			
Retrofits eliminate gas in existing residential and commercial buildings	Deploy					Complete
Electrify light-duty vehicle fleet	Deploy				Complete	
Make heavy-duty fleet net-zero	R&D and demo		Deploy			Complete
Decarbonize low-temperature heat in industry	Deploy			Complete		
Decarbonize high-temperature heat in industry	Deploy					Complete
Commercial-scale CCS & negative emission technologies	Pilots	Deploy				Complete
Decarbonize industrial processes	R&D and demo		Deploy			Complete

Note: The latter stages in this timeline are contingent, on some aspects, to international progress; they might be accelerated or delayed by a few years.

1 Introduction

Canada is not on track to reach net-zero GHG emissions by mid-century. Despite the climate policies introduced by the federal government since 2015, and optimistic assessments of Canada's 2022 Emissions Reduction Plan, a recent report from Environment and Climate Change Canada (ECCC) recognized a substantial gap remains between reductions anticipated from existing climate policies and the official 2030 and 2035 interim targets (Canada, 2025), in agreement with the *Institut de l'énergie Trottier*'s Canadian Energy Outlook (Langlois-Bertrand *et al.*, 2024). ECCC now forecasts an 18% GHG reduction rather than 40% for 2030, and 20% rather than the intended 50% for 2035 (Figure 1), a projection that does not include the negative impact of the repeal of the consumer-facing carbon levy. According to ECCC, adoption and full implementation of all other measures being considered by government (so-called 'additional measures') could partially close this gap by achieving a 30% GHG reduction by 2030 and 35% by 2035.

Without further significant action the country would therefore achieve less than half the targeted reductions. Considering the difficult political conjuncture, with turmoil over tariffs, the hostility of the current US administration to the energy transition and international climate regime, as well as the systematic overestimation of the emission trajectories by the government, even these results are far from certain. Yet, while Canada continues to dither and to miss its targets, a large number of states have succeeded in deploying strategies that deliver very sizeable reductions in emissions compatible with the Paris Agreement objectives, while remaining fully committed to their long-term objectives.

Canada's failure is not only environmental, it is also competitive: we are not moving rapidly enough to build the new economy that will be required to ensure Canadian prosperity in the second half of the century.

Many factors have contributed to limited progress. It was always going to be difficult to curtail emissions in a country with a resource-based economy, expanding oil and gas exports, widely varying regional energy political economies, decentralized political arrangements, and close economic integration with the United States. Moreover, the interim (2030) abatement target adopted by the federal government in 2021 was not based on careful bottom-up analysis but on political expediency. And, in spite of its name, **the Emission Reduction Plan was not a practical plan**, that laid out the real-world conditions required to secure emissions reduction and then ensured stepwise implementation to achieve these goals. Rather it was an aspirational modelling exercise tweaked to show the desired outcome. Policy development was excruciatingly slow (not aided by excessively complex pricing and compliance mechanisms that lacked transparency), and large amounts of political capital were wasted on initiatives that can contribute little to transitioning Canada's systems to net zero.

In this report we reexamine the challenge of decarbonizing Canada's economy by mid-century, consider the progress that has been made to date, and outline measures that can reorient efforts to make progress in key economic sectors.

Before we present the detailed analysis, **it is helpful to outline our basic approach**. To decarbonize our economy over the next 25 years, the 'gap' between ambition and practical actions must be closed. This means adopting a more strategic approach that includes:

1. Shifting focus. Instead of worrying about short-term emission reduction targets we should **prioritize real-world changes that fundamentally transform our systems**, so emissions are essentially eliminated by mid-century. Tracking physical indicators (the installation of clean electricity generation, the number of buildings converted to electric heating) and measures of market transformation (percentage of EVs in total auto sales, relative costs of gas and electric heating) in these systems is more important than tabulating annual emissions reductions.
2. Recognizing that **climate policy is increasingly linked to economic development and industrial policy**. Renewable technologies (solar, EVs) are now being adopted by poorer countries to accelerate economic development, and nations are jostling to secure their place in low carbon production chains. For Canada net zero is about building an economy that can be competitive to prosper in a decarbonizing world. Support for clean electricity build out, value-added transformation of natural resources (mining and processing critical minerals) and manufacture of low-carbon technologies (EVs, heat pumps, electrical system components, etc.), creates the foundation of future affluence, gives us tools to decarbonize our domestic economy, and can strengthen political coalitions favouring more vigorous action.

3. **Embracing asymmetrical decarbonization.** Sectors, provinces and regions will proceed down pathways, and at rates, appropriate to their circumstances. Policies should be adapted to the phase of transition in different regions and sectors. Where solutions are ready, policy measures should accelerate mass deployment. Where solutions are not yet clear, policy can support R&D, experimentation, and measures to prepare eventual market transformation.
4. **Adopting a planning and implementation mind set:**
   - **a)** *Think first about what a net zero economy would look like.* How do we organize effective systems for moving goods, heating buildings, providing electricity, and so on, that do not result in net GHG emissions? Of course we cannot anticipate every detail. But we already know the basic structure of a net zero energy system.
   - **b)** Then *ask what sequence of changes in the physical world* is required to achieve this goal. This includes the buildout of infrastructure (power plants and EV charging stations), the adoption of new end-use technologies (EVs on the roads, heat pumps in buildings), and the development and eventual adoption of novel technologies (for heavy industry, net zero aviation, carbon removals, and so on).
   - **c)** *Examine the barriers to and enablers of the desired transformation* in each specific context (the sector, province or city) and adopt appropriate policy measures to secure the physical changes that construct the future economy. By working backwards from the desired system architecture, it is possible to plan the concrete steps required to build the new economy.
   - **d)** *Monitor progress and adapt.* Current reporting practices are too slow for this transition, leading to a very static approach to policies. To be efficient, strategies must be deployed for fast monitoring of key indicators. Policies and measures must be evaluated and adapted to what is happening on the ground on an almost continuous basis.
5. **Supporting the new rather than punishing the old.** Society will not abandon fossil fuel resources because supply has been politically constrained but because demand has been eroded by superior renewable technologies and electric end-uses with higher performance, which are convenient, safer, and ultimately cheaper. So, the policy emphasis should be on rolling out the new, with a strategy to drive costs and prices down while demonstrating the benefits of new technologies, rather than penalizing the old. As fossil fuel dependence is eroded on the demand side the balance of forces between old and new energy systems, and the political calculus, will change and the transition can accelerate. But targeting fossil energy producers directly (when oil remains the country's largest export earner and several provinces' economies are based on the petroleum industry) is politically challenging.
6. **Paying attention to prices.** In the short term, prices are largely given, but over time they are influenced by investment. Learning rates (the price fall with the doubling of deployment), economies of scale and regulations can dramatically transform relative costs. Thus, the purchase price of solar panels has dopped by 90% over the past decade. Policy can help drive down the price of new technologies by encouraging uptake through procurement, training, strategic production or consumption subsidies, regulations and other mechanisms. Carbon pricing acts in the other direction, by raising the costs for fossil fuel-based options. But, as we have seen, measures that raise prices are likely to meet political resistance, and people resent an imposed loss (for example, through taxes) more than an advantage conferred to others (for example, through subsidies). More generally in navigating the energy transition governments must take care to avoid a sudden rise in energy prices (for example electricity rates), or concentrated losses imposed on a particular industry, occupational group or region, for they can spark a backlash that can derail plans for years. They must also ensure that policies drive structural changes that lower the price of the desired technologies and services.

The remainder of this report proceeds as follows: first, we provide a bird's eye view of the emissions gap between current projections and targets, comparing with similar efforts around the world. Second, we outline a framework to design sectoral strategies to correct the course and improve Canada's competitiveness in the low-carbon economy. In doing this we outline concrete transformations that need to occur if Canada instead accelerated its transition toward net-zero.

2 An overview of the gap

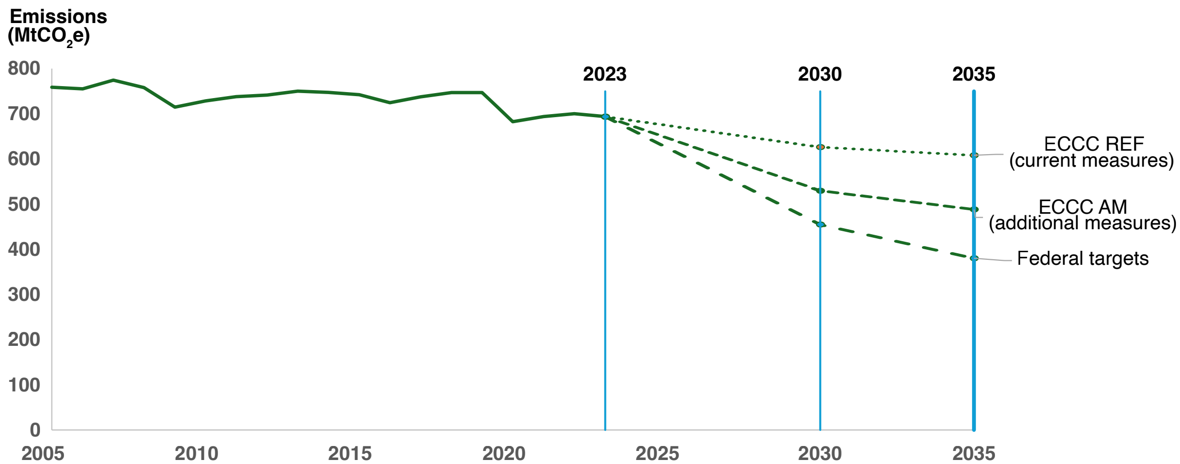
Based on Canada's latest National Inventory Report, published in April of 2025 and with coverage up until 2023, total emissions across the country were down 8.5% with respect to 2005, the reference year for Canada's reduction targets. As Figure 1 shows:

- ECCC projects that emissions will be down by 18% with respect to 2005 by 2030 and 20% by 2035
- ECCC also projects that emissions would be down a total of 30% with respect to 2005 by 2030 and 35% by 2035, if all measures currently under development[1] were enacted and ully delivered

Canada is therefore on track to miss, by far, its emissions reduction targets of -40% by 2030 and -50% by 2035.

In short, while Canada has now begun to curb emissions, current measures as well as those under development are insufficient to come close to meeting its own targets. These targets are also less demanding than those of most of its OECD counterparts, many of which have managed to accomplish much greater progress for some time now. Indeed, as Figure 2 shows, contrary to Canada, European countries have decreased their emissions significantly since 1990, with a majority surpassing their 2023 targets. To make this clearer, Figure 3 shows the evolution of emissions of European countries as well as the United States and Japan, contrasted with Canada.

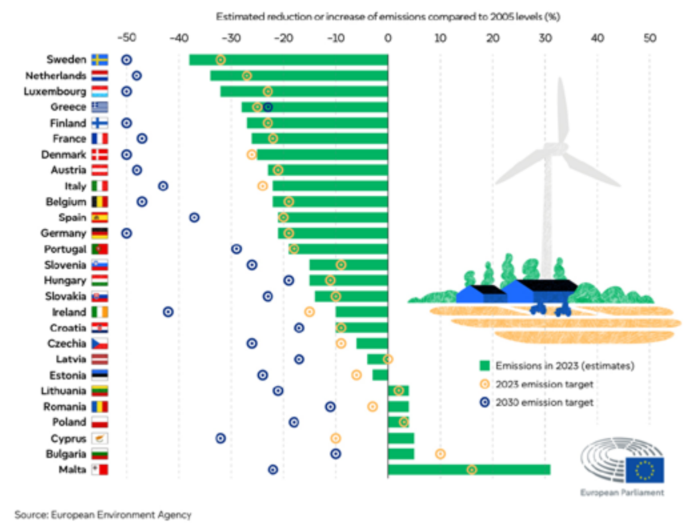
Figure 1 - Historical and projected GHG emissions according to different scenarios



Source: Canada (2025)
Note: projections from ECCC include two scenarios: a "current measures" reference scenario (REF) with the measures in place at the end of 2024 and an "additional measures" scenario (AM) with various measures under development.

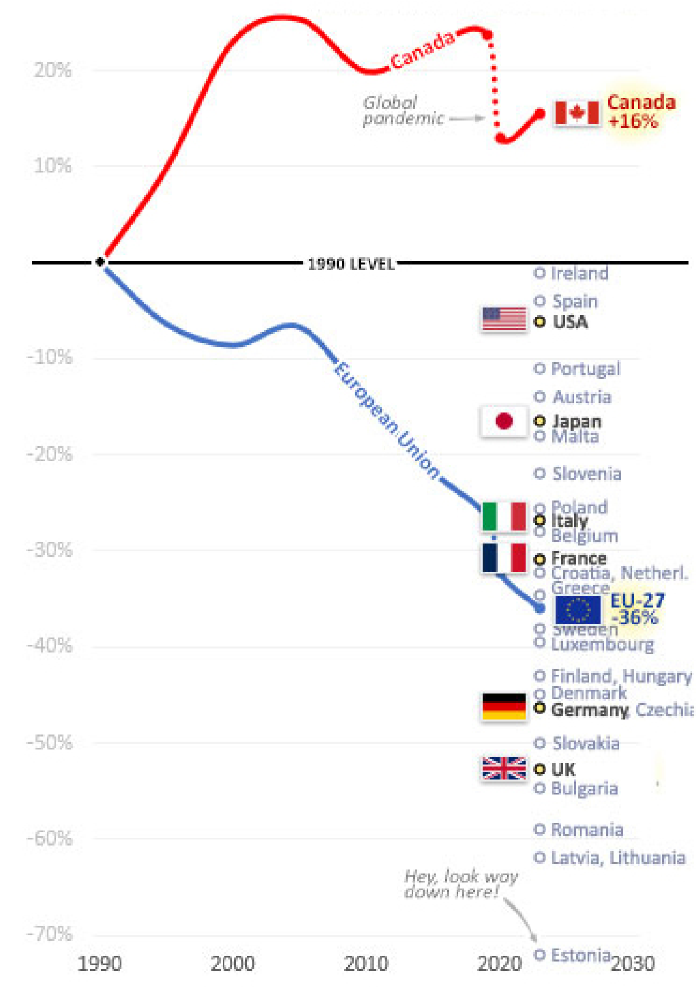
[1] These measures include, notably: a fertilizer emissions reduction target of 30% below 2020 levels by 2030; an oil and gas emissions cap, set at 27% under 2026 reported levels for the sector; a zero-emission vehicle sales mandate to medium- and heavy-duty vehicles; and the Clean Electricity Regulations, which establishes performance standards to reduce GHG emissions from fossil fuel-generated electricity starting in 2025. The full description of what is included is provided in Table A4.6.7.2 in Canada (2024).

Figure 2 - Emissions and targets by EU country



Source: European Parliament (2025)

Figure 3 - Emissions and targets for various countries

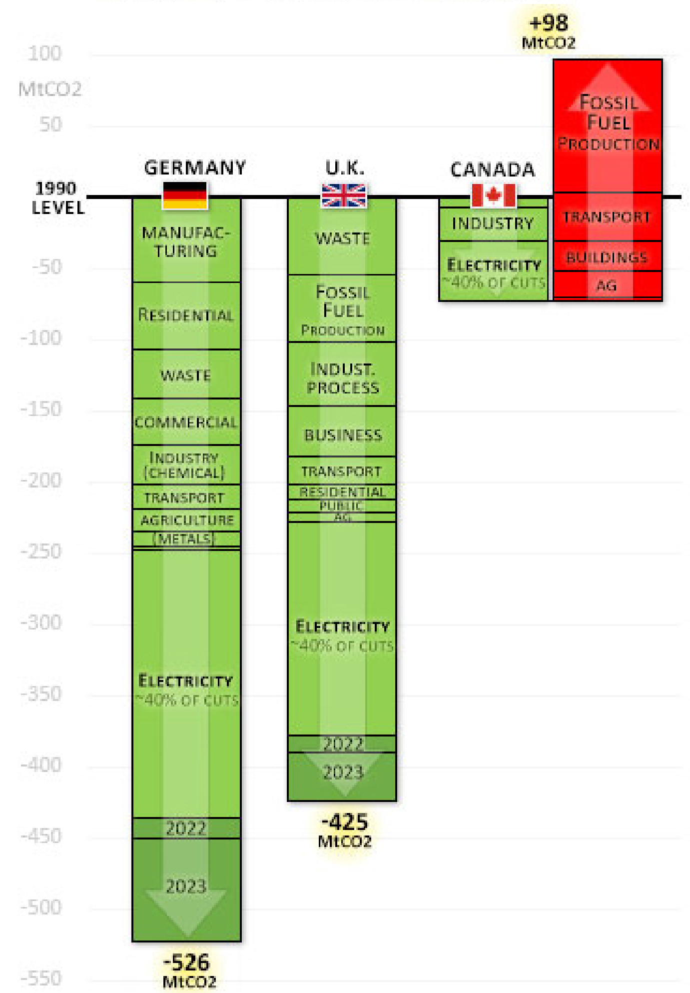


Source: Adapted from Saxifrage (2024a)

Each country, including Canada, faces its own unique challenges and conditions. Nevertheless, a large number of states have succeeded in deploying strategies that have allowed very sizeable reductions in emissions, compatible with the Paris Agreement objectives.

While national economy-wide targets are necessary to ensure meeting commitments under the Paris Agreement, sectors face very different challenges in reducing emissions, and each represents various shares of the total. Here again, Canada's peers have shown that it is possible to get reductions across sectors. Figure 4 illustrates the sectors' contribution to reductions in the United Kingdom and Germany, underlining that getting sizeable reductions necessitates sector-specific plans integrated into an economy-wide strategy.

Figure 4 - Sectoral contributions to GHG reductions



Source: Adapted from Saxifrage (2024a)

Table 1 shows the GHG emissions for each main economic sector, and the 2035 projections for each under ECCC modelling. To get a sense of the recent trends in each sector, we also include the relative change in emissions between 2015 and 2023. Table 1 also includes a sector "reference" target that will be used in the next section. While Canada has no sector-specific GHG emission reduction targets, Table 1's last column provides an evaluation of what would need to be reached by the sector (1) *if the country was to take seriously the existing 2035 target*, and (2) *assuming a contribution that is similar to the sector's share of reductions under the additional measures (AM) projections (that include measures currently considered but not deployed)*. In other words, it accepts the distribution of sectoral contributions under AM projections, and increases them proportionally to reach the government's 2035 Canada-wide target. We use the emissions in this column to give an order of magnitude of what is missing if Canada were to meet the 2035 target.

Table 1 - GHG emissions: past data, projections and targets by sector ($MtCO_2e$)

	Past emissions			ECCC projections		2035 reference target
	NIR	NIR	Recent trend	Current measures scenario	Additional measures scenario	Sector 'target' assuming government 2035 ambition and if sector contributions are proportional to those in the "Additional measures" scenario
Sector	2005	2023	2015-2023	2035	2035	2035 ('target')
Residential	45	38	-12%	32	28	17
Comm. & Inst.	40	44	+6%	38	33	28
Transport	156	157	-3%	125	118	93
Heavy industry	88	78	-1%	73	57	38
Oil & gas	194	208	-8%	200	151	123
Electricity	116	49	-34%	18	14	0
Agriculture	66	69	+6%	69	66	66
Waste	24	23	+1%	24	14	7
Total[2]	759	694		607	500	Overall target: 380 (-50%)

[2] The totals for 2035 do not match the sum of all rows, as some sources of emission are omitted for simplicity.

3 Changing course: sectoral strategies to get to net-zero

To develop effective strategies for transforming the economy and achieving decarbonization objectives, we must look closely at sectors. This section provides a brief overview of each sector, highlighting a few key cross-cutting observations."

- The gaps between current emissions trajectories and 2030 or 2035 targets are important and cannot be filled by doubling down on existing measures
- Interventions should focus more on structural transformations enabling the decarbonization of sectors and services toward net-zero
- There are considerable opportunities to enhance productivity and the competitiveness of Canada's economy in realizing these transformations, in addition to the climate benefits

To illustrate how this can be achieved, we focus on three sectors and propose an assessment of needs and a strategy to address them: **buildings**, **road transport**, and **industry**. We also provide an overview of the challenges facing other sectors, to be analyzed in more detail in a subsequent report. These sector strategies outline actions that aim to transform markets and reduce costs, thus facilitating and expediting the shift towards low-emission services. In so doing, each strategy follows similar principles for approaching the design and implementation of decarbonization measures. The framework covers:

1. What net-zero transformation looks like: what are **the key elements of an improved system** that can provide services in the sector and that does not result in net GHG emissions?
2. Which physical changes are needed to get there: what are the **essential material components** required to achieve such a system transformation, and at what pace?
3. How to overcome key barriers: what are the **foreseeable obstacles** that must be removed, in as many relevant locations around the country as possible, to facilitate the necessary changes? What measures (coordination efforts among key stakeholders, regulations, policies, etc.) can be **enablers** to support the deployment of the transformative pathway?
4. Capturing economic benefits: what **strategic economic interests** for Canada can be realized through the successful deployment of the strategy? Economic development possibilities and increasing Canada's global competitiveness, reducing costs for a given service, or improving the quality of the service, for instance.

Each strategy is then summarized in a table with the main objectives and action items for the short term (a year), medium term (1-5 years) and longer term (5-25) years.

For this report, we are accepting the government's 2035 targets as a reference point for discussion and to highlight the gap between stated ambition and anticipated system transformation (and emissions reduction) over the coming decade. This does not necessarily imply that we believe the 2030 or 2035 targets were well chosen, or that the sectoral contributions to emission reduction should be those implied in the 'additional measures' scenario, or indeed that these contributions will remain constant over time. Indeed, everything we know about market transformation suggests the process is not linear, but takes place slowly at first, then accelerates, and then slows again. And these changes will not be aligned across different sectors and regions, so their relative contribution to emission reduction will vary at different points in time.

The real goal here is an essentially decarbonized economy by mid-century. And this will require transformative measures along the lines discussed in the sections below over the next 20-30 years. Whether one thinks that the target for a particular sector is too stringent or not sufficiently stringent; and whether a specified degree of market transformation is achieved in 2031, 2035, or 2039, the same general sequence of changes discussed below, and reductions on something like the same scale, will be required for any feasible plan to reach net zero by mid-century. If change is to be slower in earlier years, then it will heave to be more rapid in subsequent periods as technologies mature, prices fall, and infrastructure is built up. So the basic steps outlined in the sectoral strategies below remain the same whether we dig in our heels next year or continue to defer action. Of course, the window for Canada to seize opportunities in international net-zero supply chains, may close as other countries pursue more vigorous action.

3.1 Buildings

The buildings sector encompasses a wide range of structures, from very small buildings (small single-family homes, for instance) to very large ones (such as commercial facilities, high-rise office towers or multi-unit residential buildings).

Residential buildings emit GHGs largely due to combustion-based space heating services (75% of the total in 2022), and, to a lesser extent, water heating (24%) and appliances (1%) (see Table 2). In commercial buildings, the space heating service represents an even larger share of this subsector's emissions (86%). Since 2015, residential buildings emissions have shown a modest downward trend (-12%)[3] while commercial buildings emissions have moved upward (+6% since 2015), resulting in emissions for that sector that remain higher today than in 2005 (see Figure 5 and Figure 6).

Given the sources of building emissions, most efforts to decarbonize buildings have so far focused on replacing emitting heating, ventilation and cooling (HVAC) systems with low-carbon ones (for instance, switching an oil furnace to an electric heat pump) and improving the energy efficiency of the building envelope (for instance, by improving insulation of older buildings).

Table 2 - GHG emissions from residential as well as commercial and institutional buildings in 2022 (excluding electricity-related emissions)

Service	Residential ($ktCO_2e$)	Commercial/ institutional ($ktCO_2e$)	Total ($ktCO_2e$)	Percentage of Canada's total emissions
Space heating	29.400 (74.4%)	29,300 (86.2%)	58,700	8.3%
Water heating	9,600 (24.3%)	3,300 (9.8%)	12,900	1.8%
Total			71,600	10.1%

Source: OEE (2025)
Note: percentages in the first two columns indicate the share of total emissions within each building type

[3] It should be noted that a very large part of the year-to-year fluctuations in buildings emissions can be attributed to variations in the number of degree-days of heating required each winter, which directly influences the energy demand for heating in buildings (see Langlois-Bertrand and Mousseau 2024, pp. 30).

3.1.1 The size of the gap

ECCC projections show that the emission reduction rate for buildings would need to be multiplied by a factor of 4 to get close to the 2035 GHG target.

Concretely, to get somewhere close to the 2035 reference target, over the next decade we would need:

- All new constructions to be net-zero, and
- At least 5 million residential units without electric heating (60% of all residences) be fully decarbonized OR that 7.6 million would be set to hybrid heat pump systems, and
- 40% of commercial and institutional buildings without electric heating switch to all-electric OR 60% switch to hybrid heat pump systems (600,000 buildings).

3.1.2 Further implications of closing the gap

Growing the size of existing programs, even setting aside questions of effectiveness and financing, would not be sufficient. If the changes outline above were to be realized, they would also require that:

- All provinces adopt net-zero building codes, and
- New measures support the development of heat pump supply chains to bring down costs, especially for commercial buildings, and
- Electricity grids are expanded/upgraded and winter peak issues are managed even more quickly (ahead of needs).

This last point on electricity needs is particularly important: installing electric heat pumps in more than 5 million buildings would lead to additional zero-emission electricity needs of 130 TWh (+20% compared with national electricity production today), with an even more pronounced upgrade of distribution grids of about 40% in power distribution capacity to support winter demand.

Decarbonizing buildings in an order of magnitude compatible with the 2035 reference target therefore involves much more than incentive programs for building owners: it requires a major upgrade of electricity systems to accommodate demand, and this must occur within a regulatory framework where at least new constructions rapidly become much more energy efficient.

Figure 5 - Historical and projected GHG emissions from residential buildings

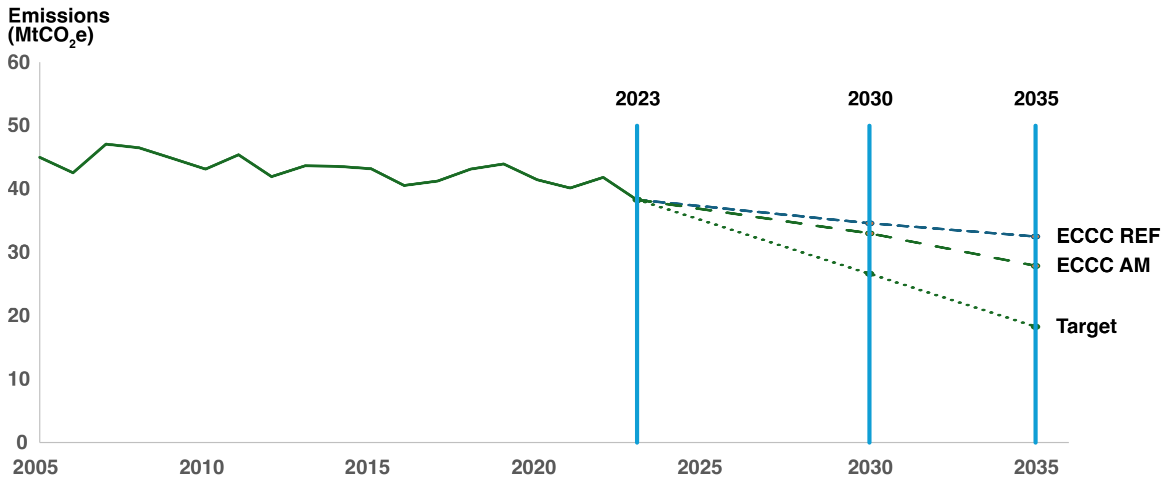
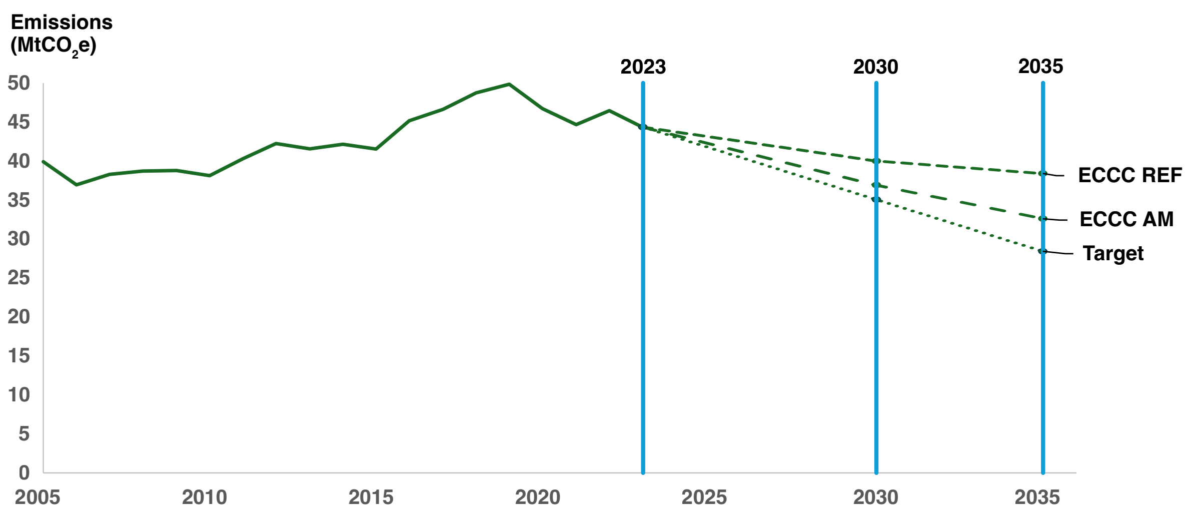


Figure 6 - Historical and project GHG emissions from commercial and institutional buildings



Note: AM scenario includes, notably, the Canada Green Building Strategy, more stringent efficiency standards for appliances and equipment, and net-zero energy ready building codes by 2030

3.1.3 Decarbonization options for space heating and cooling

Given that they constitute a large majority of emissions in buildings, we focus on the decarbonization of operational GHGs linked to space heating, which essentially come from the emitting energy sources used to provide the service. This includes natural gas, and, to a lesser extent, heating oil, although oil retains a large share of the total in some regions of the country. Water heating is often provided with the same energy source as space heating.

What net-zero transformation looks like: key elements of an improved system

Although several zero-emission technological options exist for providing heating in buildings, there is general agreement that heat pumps will provide the lion's share of this service as they can offer both heating and cooling services very efficiently. This is particularly relevant to Canada where space cooling is the energy service with the fastest growth in the buildings sector. Leveraging these investments in air conditioning can therefore contribute to a significant reduction in the marginal cost of replacement fossil-fuel-based heating systems with air- or ground-source heat pumps. Moreover, it should be noted that converting heating and cooling to electricity often provides an opportunity to electrify water heating, which implies an additional decarbonization benefit.

We note that the current situation on decarbonizing space heating and cooling across the country is very uneven, even though many of the challenges are similar. Therefore, success in one region is likely to hold lessons for other areas of the country.

Strategic opportunity for Canada

Today, air source heat pumps dominate as the main building heating decarbonization solution deployed in various parts of the world (IEA 2025). In cold climates, these technologies see their efficiency advantage diminished by higher electricity requirements in the coldest part of the year, putting pressure on electric utilities to develop innovative peak management strategies to avoid unnecessary buildout of capacity just to ensure adequate supply for a few hours a year. Moreover, for large commercial and institutional buildings, there is still relatively little experience around the world to operate heat pump systems efficiently. Therefore, there are significant business opportunities for Canadian firms to develop innovative solutions to meet these challenges.

Physical changes needed to get there

Decarbonizing this sector rests on successfully accelerating three components: (i) the installation pace; (ii) the electricity supply and (iii) the management of winter peak electricity demand. More specifically, deploying heat pumps in both new and existing buildings at a pace compatible with GHG reduction objectives requires rapidly ramping up installations in both residential and commercial/institutional buildings. This means supporting training and the creation of efficient supply chains, providing information to both installers and clients, and driving prices down through structurally efficient measures.

In order to facilitate this acceleration in the deployment of heat pumps, electric utilities will have to rapidly increase their generation capacity to accommodate the increase in electricity demand from these systems and upgrade local electricity distribution capacity to allow for deployment anywhere needed, in all provinces.

Key barriers to overcome

Realizing the pace of installations suggested above and the electricity capacity buildout can be made possible by a series of conditions structuring the effort on four fronts.

In spite of their large-scale worldwide deployment, installing **residential heat pumps** remains expensive. A central point of focus, to increase their adoption, rests on the development of strategies to reduce their price tag. This can be done by structuring demand, through for example, a ban on fossil-fuel use in new buildings, strategic subsidies, increased competition, recommendations and guides, and regulation.

High performance heat pumps and heat-pump-based commercial HVAC systems must be made available with strategic support and programs to ensure the lowest possible costs across the country. This implies extensive supply chains that produce and install cheaper devices and systems for all types of buildings. While manufacturing will continue to be dominated by foreign businesses, Canada must develop a strong service industry to match the transformation of demand in the sector, including some manufacturing but also engineering, installers, maintenance and operators. The particular importance of rapidly developing retail systems for expertise cannot be overstated – for installation but also maintenance, parts and repairs, as well as operation and optimization.

Indeed, while standard residential heat pumps are readily available, commercial and institutional heat pumps must still be specifically designed and assembled, increasing installation and maintenance costs. As this sector is underdeveloped on the international scene, it represents a strong business opportunity for Canada.

Alongside this structuring of heat pump markets, **building codes need to be upgraded** to rapidly make new constructions, at all scales, adopt low-carbon technologies, in particular by maximizing the thermal envelope's efficiency to minimize energy needs for heating and cooling and by preventing new gas furnace installations.

While the electricity infrastructure across the country is for the most part sufficiently robust today to allow the incremental addition of heat pumps, a transition to electrified heating on the scale envisioned above will require a steady deployment of **new generation capacity together with upgrading of transport and distribution networks** to keep ahead of the demand to prevent wasted investment in fossil-fuel heating technologies.

Enabling the supply of electricity needed for these installations requires optimizing the buildout of electrical grid upgrades to minimize the cost associated with this infrastructure. While heat pumps are significantly more efficient on average than other types of heating systems, their efficiency drops in very cold temperatures. This results in a peak demand for electricity for the coldest hours of the year. So mass deployment of heat pump systems requires **winter peak management strategies** implemented by utilities, so that the impact on the grid is minimized. The absence or limited deployment of such strategies is already a major limitation to decarbonizing the building sector. These types of strategies are essential to ensure that capacity constraints do not prevent well-developed markets from delivering the accelerated pace of installations, and that utility costs do not explode and drive rates upward as a result of heat pump deployment.

Box 1.1 - What is winter peaking?

Demand for electricity typically follows three levels of cycles: daily (morning - evening), weekly (workdays - weekends or public holidays) and annual (seasons). Demand is closely linked to the variation in outdoor air temperature below or above a certain threshold during winter and summer respectively. The lower the temperature in winter, the higher the demand for electricity for certain uses, such as space heating or charging electric vehicles. The heat sensitivity of demand is not always linear, because of the impact of certain equipment such as heat pumps - which require auxiliary heating when temperatures are very low - and the thermal insulation of building envelopes.

Peak electricity demand corresponds to the periods of the year when demand for electricity is highest. These peaks may be linked to the daily cycle (intraday peak) or the annual cycle (seasonal peak). While a large part of Canada is still experiencing daily summer peaking associated with air conditioning, as heating becomes electrified, the winter peak demand dominates by far. Summer peak for Québec, where residential heating is more than 85% electrified, represents a bump of about 2 GW on a base of 20 GW, while, over 20-30 hours, the winter peak can lead to a jump in demand of as much as 8 GW, on a winter base load of 33 GW (see Section 3.7 for more details) (Edom et Mousseau, 2023 and 2025).

These enabling factors can be deployed with the help of several measures:

- All provinces adopt net-zero buildings codes and/or energy performance standards compatible with the objectives above
- Regulation on the installation and management of heat pumps, particularly for commercial, institutional and multi-unit residential buildings aims at removing hurdles and bias in favor of fossil fuels
- Utilities deploy infrastructures to meet the resulting increased demand
- Utilities exchange best practices on winter peak management and map out distribution capacity constraints to target upgrades with the view of accommodating rapid and large-scale heat pump deployment
- Training is provided to all commercial/institutional building operators or managers above a certain size
- Independent intermediary actors like the Building Decarbonization Alliance help coordinating the gathering and sharing of data across the country on progress and measures deployed

More details are provided in Table 3.

Economic benefits to be captured

While most manufacturing of heat pump equipment is likely to remain outside Canada, there are significant job creation opportunities in providing operation, maintenance and repair expertise to accommodate the various types of installations, particularly in commercial and institutional settings.

More importantly, all northern countries will be facing a winter peak electricity demand as they decarbonize. This is an opportunity for Canada to take the lead in the technologies and management strategies aiming to efficiently manage this peak.

Table 3 - Decarbonization strategy for buildings: objectives and action items

RESIDENTIAL BUILDINGS	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Send a clear signal that Canada is aiming for more than half of residential buildings to be equipped with heat pumps within a decade and zero-emission systems to be a requirement of new buildings	Expand a heat pump service and supply industry by ensuring a market in all regions of the country; start reducing prices	By 2040: Achieve electrification of space heating in 80% of existing residential buildings; create a robust and export-competitive service and supply chain industry for heat pumps; deploy building-related peak management strategies for electricity grids in all provinces
Action items	1. Adopt building energy performance standards and upgrade building codes in all provinces to make non-emitting heating systems mandatory for the primary heat source (in both new buildings and in system replacements) and make very high performance building envelopes the new minimum (for new buildings) 2. Map out capacity bottlenecks in electricity distribution grids that require urgent attention for short-term deployment of heat pumps and begin planning and execution of upgrades	1. Develop a strategy to expand the service industry associated with heat pump systems and peak management solutions 2. Support the development of efficient supply chains for heat pump parts and devices in all provinces (local suppliers, repair expertise, etc.)	
COMMERCIAL BUILDINGS	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Send a clear signal that heat pumps will be made to dominate new space heating system installations in all types of MCI buildings by 2030.	High performance heat pumps and heat-pump-based commercial HVAC systems are available at the lowest possible costs across the country	By 2045: Achieve decarbonization of MCI buildings in all provinces; create a robust and export-competitive service and supply chain industry; deploy MCI building-related peak management strategies in all provinces
Action items	1. Adopt building energy performance standards and upgrade building codes in all provinces to make non-emitting heating systems mandatory for the primary heat source (in both new buildings and in system replacements) 2. Identify and reduce regulatory barriers to the use, maintenance and repair of heat pumps in large buildings and start process to lift them 3. Deploy and test peak management solutions 4. Map out export opportunities for peak management solutions 5. Develop information-sharing among utilities for experience and best strategies in resolving capacity constraints and deploying peak management solutions	1. Deploy a strategy to develop a supply and service industry for the various technologies adapted to the various segments, with support for increasing their competitiveness 2. Support the deployment of electric infrastructure to facilitate extended electrification 3. Use public sector procurement to support new technologies for peak management in large institutional buildings 4. Develop regulation for preventing the deployment of natural gas low-temperature heating for new buildings and furnace replacements	

3.2 Transportation

In this section, we will consider all transport by road, including light and heavy-duty vehicles for passengers and freight.[4] Emissions in this sector have grown between 2005 and 2019, reaching 131 $MtCO_2e$. After a 17% drop in 2020, to 110 $MtCO_2e$, emissions are growing again and have reached, in 2023, the level of 2005.

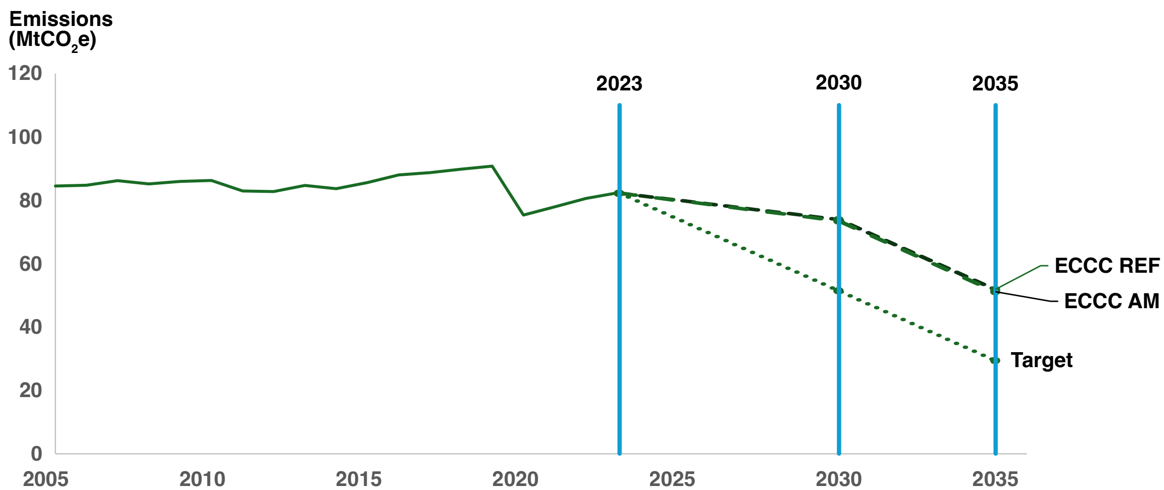
Emissions from passenger transport, which are primarily generated by light-duty vehicles (cars and trucks), are expected to decrease to a similar extent under both the current and additional measures ECCC scenarios. This assumes, however, maintaining the zero-emission vehicles (ZEV) sales mandate and fully realizing its targets – according to which retailers are to have ZEV take up 60% of their total sales in 2030, and 100% in 2035. While the mandate is officially technology-neutral, electric vehicles are expected to provide almost all that is needed to meet the obligation, with British Columbia and Quebec already well over 20% of annual sales already (24% and 30.9% in 2024, respectively). These projections suggest a 39% (33 $MtCO_2e$) decrease in emissions from passenger transport from 2005 levels by 2035.

Table 4 - GHG emissions from road transport

Sector	2005 ($ktCO_2e$)	2023 ($ktCO_2e$)	Percent of Canada's total emissions
Light-duty vehicles	84,509	82,256	11.7%
Heavy-duty vehicles	42,261	42,991	6.1%
Total	126,770	125,247	17.8%

Source: ECCC (2025)
Note: due to data availability, emissions for heavy-duty vehicles for freight transport include a very small portion associated with rail transport

Figure 7 - Historical and projected GHG emissions from road passenger transport



[4] Off-road transport (for onsite machinery, for instance) is also important, but a different classification of emissions from this segment depending on the methodology used (economic sector vs. IPCC category classification) leads to an important discrepancy in their share for the transport sector as a whole. For simplicity, we focus here on categories as used in ECCC projections, where off-road is a much smaller share of the total (<10%). Under the economic sector classification, most off-road emissions are attributed to the sector where they occur (industry, agriculture, commercial and residential). See Langlois-Bertrand and Mousseau (2025) for a more detailed explanation and overview of emissions from these sources.

The evolution of freight transport emissions is less clear-cut. While both ECCC scenarios show a modest but steady decrease of emissions before 2030, extending this trend beyond 2030 depends on the implementation of a ZEV mandate for medium- and heavy-duty vehicles, currently under development. Without this hypothetical regulatory constraint, emissions bounce back up in the reference scenario, approaching 2023 levels.

The forecast decrease in emissions from freight transport over the next few years is largely the result of the impact of the Clean Fuels Regulation kicking in. The impact of this regulation remains limited in addition to being incompatible with a net-zero target.[5] Moreover, its impact will likely be decreased by the recent amendment made by the federal government, which exempts Canadian biofuels producers from having to meet the same emission-reduction thresholds. No further measures are expected to support structural transformations in the sector.

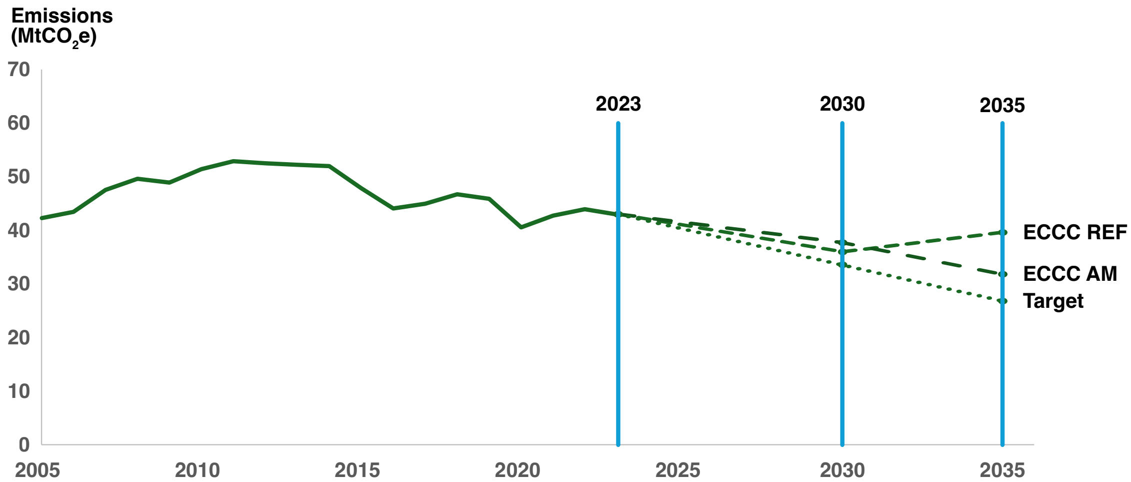
3.2.1 The size of the gap

While the expected decrease in passenger transport is significant, it is important to note that realizing these projections would require that from now to 2035:

- All provinces (including the majority where EV sales still remain below 1%) take vigorous policy measures to encourage EV adoption (for example through the implementation of the ZEV sales mandate), and
- Extensive charging infrastructure is deployed across the country, and
- Costs continue to fall as options for zero-emission vehicles become more diverse, and
- A ZEV mandate or other appropriate measures are also deployed for merchandise transport, aiming for 15-20% of zero-emission trucks by 2035, supported by the necessary energy infrastructure (chargers, catenaries or hydrogen).

While this may look like a reasonable acceleration in provinces where the ZEV trend is already underway, especially since it aligns with the orientation of many other countries, it represents a fundamental transformation of the fleet and of the provision of this service for all other provinces. Even if avoiding concerns about the availability of equipment for purchase and installation (both vehicles and chargers), planning for their very rapid deployment would have to begin immediately.

Figure 8 - Historical and projected GHG emissions from road merchandise transport



Note: additional measures (AM) scenario includes a partial medium- and heavy-duty vehicles (ZEV) sales regulation with 2030 and 2040 targets; due to data aggregation in ECCC projections, numbers shown include non-road merchandise transport

For freight transport, really deep transformation will extend beyond 2035. However, measures in place are not expected to set a downward trend. If the medium- and heavy-duty ZEV mandate were to be put in place and implemented as assumed in ECCC's additional measures scenario, this trend could indeed begin, but the success of this measure is dependent on many factors. In particular, it assumes that the sector, across all regions in the country, can rely on a buildout of large-scale energy transport and distribution infrastructure to power truck fleets, regardless of the chosen decarbonization option (hydrogen, battery-electric vehicles, catenaries, or even renewable diesel for certain specific niches). Additionally, just like for passenger transport, the success of the ZEV mandate assumes its implementation across all provinces.

While road vehicles constitute the bulk of emissions for freight transport, it is worth noting that ECCC projections do not foresee any reduction from either air or marine transport, two sub-sectors where technologies are not sufficiently developed at the moment to expect a rollout before 2035.

[5] The Clean Fuels Regulation is not compatible with a net-zero target for two main reasons: first, the production of "clean" fuels comes with lower but non-zero emissions; second, there is not enough biomass feedstock to produce enough fuel to replace all fossil-sourced fuel used for transportation.

3.2.2 Further implications of closing the gap

The requirements above for closing the gap and ensuring sufficient emissions reductions in passenger and merchandise transport have many implications. Alongside the deployment of charging infrastructure, the full impact of the ZEV mandate for passenger transport necessitates an expansion of electricity production (+88 TWh nationwide/+14% with respect today). This increase is not just large: it is proportionally more challenging, for provinces with limited existing charging infrastructure; and the contribution of this demand points to grid capacity constraints that may prevent a rapid EV rollout in some regions unless these issues are resolved rapidly as well. We revisit this matter in Section 3.7.

When it comes to freight transport, all decarbonization options require a very significant buildout of transport and distribution infrastructure in all provinces. Additionally, a key distinction from the same point regarding passenger transportation is that to keep costs as low as possible for this expansion, choices need to be made for each region's favoured technology. This, in turn, necessitates an alignment of choices with neighbors, including U.S. States, as long-haul transport crosses borders on longer routes and needs to be treated carefully in this planning.

For all sectors affected by a sales mandate as the main tool to decarbonize vehicle fleets, it is worth reiterating that to reach ZEV targets as planned, the energy distribution infrastructure buildout would need to be rolled out in close synchrony or even largely ahead of vehicle sales. Otherwise, it is hard to see how transporters would buy vehicles for which they are unsure of the charging or refuelling availability. This could constitute a severe impediment to the sucess of ZEV mandates on their own.

To develop our strategy, we have separated this sector into three large families for technological reasons: light-duty cars and trucks, whose main use is for passenger transportation; heavy-duty vehicles for local transport, with a round-trip distance of less than 250 km; and heavy-duty long-range transport, with a daily distance of more than 400 km.

3.2.3 Light-duty vehicles

Light-duty vehicles, which include cars and light-duty trucks represent two thirds of emissions associated with on-road transport. These vehicles are covered under the current ZEV mandate that requires all new light-duty vehicles sold in Canada be zero-emission by 2035. This is in line with other G7 nations, except the United States (where a number of states, including New York and California, nevertheless share the same legal objective[6]), despite some recent contestation over the target year in some of these countries.

Strategic interest for Canada

As the rest of the world is accelerating the deployment of zero-emission light-duty vehicles, Canada is rapidly losing its competitive advantage in that field. With limited ambition, Canada is missing on the associated intellectual property, the manufacturing know-how and the capacity to produce goods that meet international standards. While a strong alignment with the USA's current position could benefit Canada on the short term (1-3 years), over the longer term delaying the shift to EV production it will be detrimental to its auto sector. Canada's industry could fall even more behind the rest of the world, as electrification is tightly associated with the most advanced automation technologies (including autonomous vehicles), building on the tight integration of AI and sensors.

[6] Fifteen states, including Washington, Oregon, Colorado, New Jersey, New York and California have adopted a ZEV mandate imposing 100% zero-emission vehicles by 2035 based on California's *Advanced Clean Cars regulations.*

What net-zero transformation looks like: key elements of an improved system

The challenge of electrifying light-duty vehicles has essentially been solved from a technological and economic point of view. North American manufacturers can deliver today fully electric vehicles at a price that continues to approach that of vehicles powered by internal combustion engine at purchase (although at present profitability is lower than for ICE vehicles because of massive investment required to develop new production chains). Of course, EVs provide significant economies with fuel and service. Globally, electric light-duty vehicles are already more sophisticated and cheaper than those running on fossil fuels thanks to Chinese manufacturers. While some issues remain, regarding vehicle range and charging networks, especially in Canadian winters, these are being rapidly addressed and, in most locations across the country, do not represent a real technical barrier.

Physical changes needed to get there

Decarbonizing this sector rests on successfully accelerating three components: (i) the rapid increase of the share of electric vehicles in total sales; (ii) the rollout of reliable and extended charging infrastructure targeting all clienteles; and (iii) the increase of the electricity supply where needed. More specifically, electric vehicle adoption rates must increase in all provinces, which requires much cheaper and widely available retail options, in addition to readily available charging infrastructure, both public and private. This means supporting the deployment of both vehicles and chargers in regions and building types where they have been slow to takeoff, taking lessons from various regions in British Columbia and Quebec where this rollout has far outpaced the rest of the country.

To support this acceleration in charger deployment, electric utilities will have to ensure that distribution grid constraints are not causes for worry in any given region. In many cases there might be planning opportunities that combine with building electrification requirements explained in the previous section.

Key barriers to overcome

In the last few years, following the Inflation Reduction Act adopted under President Joseph Biden, Canada has deployed considerable efforts and money to attract large battery component manufacturers and battery assembly plants. Their survival is uncertain as the United States is pulling out, and Canada is sending mixed messages about its plans. In parallel, Canada has imposed a 100 per cent tariff on Chinese EV imports, as these high-quality vehicles are produced at price points significantly lower than those currently available on the Canadian market. Together, these recent events contribute to slowing down the electrification of the Canadian light-duty vehicle sector.

As Canada largely sits as an observer in the international race to produce ever more sophisticated light-duty vehicles, it is also missing out on potential advances related to energy storage, high-power electronics and the fundamental transformation of the transport sector at it moves towards fully self-driving vehicles.

Instead of walking away, Canada should therefore maintain a strong ZEV mandate and leverage its 2035 objectives regarding zero-emissions light-duty vehicles by:

1. Ensuring the creation of a strong charging network across the country, ensuring both high-power/high-speed charging for travellers, and low-power/low-speed for daily use. This requires to:
   - **a)** Draw a rapid plan to allow utilities to act accordingly, and
   - **b)** Adapt regulation to facilitate the deployment of electric vehicles and charging stations, and
   - **c)** Combine with a procurement approach that can serve to promote local manufacturers
2. Adopting a strategy to encourage manufacturers to lower prices, for example, by presenting a schedule to slowly reduce import duties on Chinese EVs or bring in Chinese manufacturers
3. Leveraging Canada's drive to zero-emission vehicles to strengthen its supply chain, from minerals to high-value products
4. Enhancing Canada's role in sensor and control technologies, for instance by:
   - **a)** Setting up regulatory sandboxes to facilitate development and testing of self-driving technology adapted to Canada
   - **b)** Using procurement to create the initial market

More details are found in Table 5.

[0] President Trump adopted resolutions, in June 2025, to repeal these mandates, but a coalition of states has filed a lawsuit to invalidate these.

Economic benefits to be captured

By forcing auto manufacturers to accelerate their transformation, the government can improve their long-term competitiveness. It can also strengthen its critical mineral strategy, building on a national market for batteries and other high-tech products related to zero-emission vehicles.

Combining the ZEV mandate with an innovation strategy might help Canada find its place also in the coming automated and self-driving industry. This is crucial since knowledge and experience gained here will have broad applications well beyond light-duty vehicles.

3.2.4 Heavy-duty local road transport

This category includes a broad range of types of vehicles, such as delivery trucks, public and school buses, short-distance 18-wheelers, waste collection and other municipal services, etc., that are used for short-range trips (less than 250 km return). All these can be battery-operated to accomplish their daily tasks or a full trip without charging.

The challenges observed with the electrification of school buses in Québec underlines the importance of adopting a solid and realistic strategy to ensure successes. The Quebec government opted to support a single local provider (Lion Électrique) by investing in the company and heavily subsidizing bus purchases, without a strategy to ensure quality and drive prices down over time. Even today, electric school buses cost more than $240,000 over their diesel equivalent. While this approach allowed the company to take off and reach market, without a clear strategy to lower prices and solid quality control, Lion Électrique found itself unable to become competitive without continuing massive subsidies.

Strategic interest for Canada

The diversity of platforms and vehicles for short-distance heavy duty transport means that local manufacturers can emerge with the support of a clear policy pushing zero-emission vehicles for local transportation, just as it has already done in many other countries. As with light-duty vehicles, AI and automation will be integrated in most of these vehicles; it is therefore essential for Canada to understand and develop strategies able to leverage the AI and high-tech sector by not only funding innovation, but creating the appropriate market conditions to allows large-scale production in step with the rest of the world.

What net-zero transformation looks like: key elements of an improved system

Unlike light-duty vehicles, where a few international manufacturers dominate production, many zero-emission heavy-duty vehicles are produced by small to medium-size companies more sensitive to the specificity of local markets. This sector could therefore represent a relatively easy entry point for the development of Canadian intellectual property and knowledge contributions to the design and production of electric vehicles. Similarly, heavy vehicles offer a strong potential for a standardized battery-swapping approach, that can even out power demand for charging and standby time for vehicles. Canada could therefore also be present in this sector that is now being developed.

Finally, as electrification is essential for seamless AI integration, a strategic electrification of this sector should include high-tech sectors in areas such as sensors, control and AI.

Physical changes needed to get there

The range of services covered by local transport means that subsector strategies must be adopted to take account of the availability of zero-emission solutions, the costs of deployment, as well as potential safety issues. Decarbonizing local heavy-duty transport hinges on (i) the development of a broad offer of models and technologies that can meet each subsector's needs; (ii) the deployment of supporting infrastructure and electricity supply; and (iii) the use of innovative technological options to maximize the benefits of these transformations, for instance taking advantage of AI and automation in transport systems.

Key barriers to overcome

Given the important variations across regions and subsectors for this segment of transport, the accelerated deployment of energy supply infrastructure is likely to vary as well, making planning for each subsector essential moving forward.

Enabling factors are essential to drive private investments and create a Canadian industry for a sector that can be more easily led by smaller-scale actors, contrary to light-duty vehicles.

More specifically, these factors include:

1. Adopting a clear vision for the electrification of this sector, with a proactive approach to innovation and access to market, and
2. Adapting regulation to remove barriers to electrification, including charging and battery swapping, and
3. Deploying efficient and targeted strategies to
   a) Fund product development and manufacturing, including charging infrastructure
   b) Create a market with long-term visibility
   c) Push for competitiveness through strategic subsidies
   d) Make use of procurement strategies to support access to market and competitiveness, and
4. Using sandbox regulation to support innovation, pilot testing and access to market
5. Developing resiliency and safety procedures to remove real and perceived risks of electrifying critical segments of this sector.

More detail is found in Table 5.

Economic benefits to be captured

The heavy-duty local transport sector is already getting decarbonized in China and Europe. Without a solid strategy built on regulation pushing the electrification of this sector, Canada will miss an opportunity to create a local industry with export potential. This industry is not only about batteries, but also about high-tech and AI that is coming as these vehicles become more and more autonomous, adding to the competitive risks for Canada to miss out on this transition.

3.2.5 Long-haul road transport

This category focuses on heavy-duty trucks, including semi-trailer trucks, used for long-distance freight transport, but also includes services such as inter-regional public transport by buses. Because of the weight carried and the distance travelled daily, long-haul road transport presents particular technological challenges that have not been met satisfactorily today. Battery-operated trucks, for example, present a range that is insufficient, particularly in the Canadian context, to allow for sufficient cargo. Fuel-cell hydrogen-based truck, for their part, suffer from high cost both for the truck and the fuel, while catenary solutions would require extensive infrastructure to be built ahead of any deployment, carrying an important risk should other technologies win.

If the technological solution for long-haul is not batteries, additional infrastructure will need to be deployed, adding to the cost and challenges. These can only be minimized with the adoption of a clear direction regarding the selected technology.

Even though no dominant technology has emerged yet, progress is occurring; as for many other low-carbon technologies, it is led by China. For Canada to be able to benefit from the intellectual property, technological and knowledge, it must develop a pro-active research-development and manufacturing strategy. As with the other sectors, automation and self-driving are being developed rapidly in a tight integration with the drive train electrification increasing the economic competitiveness issues associated with decarbonization of this sector.

Strategic interest for Canada

The challenges of electrifying heavy-duty long-haul road transport are also found in many off-road sectors that are particularly important in Canada, including forestry and mining. As decarbonization of this sector will rely on a broad spectrum of technologies, including AI, sensors and automation, Canada has a strong incentive to be involved in the development of competitive solutions and work to create a Canadian manufacturing basis for the trucks and the charging, refuelling and fuel production infrastructure, potentially leveraging Canada's CCS technologies that would allow the production of low-carbon blue hydrogen or the geological potential of Canada for white hydrogen.

What net-zero transformation looks like: key elements of an improved system

While there is considerable push, today, for clean fuels from biological sources to lower emissions from the transport sector, this solution represents a dead-end pathway as it is not compatible with net-zero objectives. The long-haul road transport sector will therefore have to electrify (with batteries or fuel cells), like the other sectors.

Depending on the technological solutions that dominate, Canada could count on a number of potential advantages in the development of solutions for low-carbon long-haul freight transport. This includes the potential to produce low-carbon hydrogen with CCS as well as the presence of Ballard, a fuel-cell manufacturer. A battery solution could leverage the critical mineral strategy, adding to the demand from the light-duty and short-haul transport sectors.

As with local transport, electrification will come in parallel with automation requiring contributions from high-tech industries, including telecommunication, AI and sensing, where Canada is also present.

Physical changes needed to get there

Decarbonizing long-haul road freight transport means electrifying the fleet, as electricity is three to four times more productive than any combustion-based solution. However, there is no dominant technological solution to provide the mobile energy and power to move freight on long-distance. Physically, this means that to decarbonize this sector, it is necessary to (i) identify the preferred technology (only battery, battery, catenary plus battery, hydrogen with fuel-cells); (ii) plan models for infrastructure (private, public, mixed); (iii) support the development the energy-supply infrastructure (chargers, catenaries, hydrogen production and distribution); (iv) support the production of the various equipment, including trucks, and accompanying service industry; (v) couple these developments with a modernisation of highways, to facilitate integration of AI and automation.

Key barriers to overcome

Enabling factors are essential to drive private investments and create a Canadian industry for a sector that will require coherent vision and coordination as infrastructure investment will be substantial.

More specifically, these factors include:

1. A timeline for the electrification, via battery, hydrogen or catenaries, of this sector, and
2. Adapted regulation, including on the deployment and ownership of infrastructure, and
3. A deployment of efficient and targeted strategies to
   a) Use sandbox regulation and funding to support innovation
   b) Test and fund development and pilot projects
   c) Create a market with long-term visibility to facilitate investments
   d) Structure the service and supply chain industries through strategic subsidies
4. Procurement strategies to support access to market and competitiveness.

Economic benefits to be captured

Across the world, the long-haul transport sector might adopt different solutions as a function of the local environment. For example, regulation in Europe imposes a strict 90 km/h limit for trucks with the obligation for drivers to stop every 4.5 hours for 45 minutes; this is compatible with battery-powered heavy-duty trucks.

There are no such constraints in Canada, making other technological choices possible. Yet, without a solid strategy built on regulation pushing for the electrification of this sector, Canada will miss an opportunity to create a local industry with a potential for export. As with local heavy-duty transport, this industry is not only about batteries, but also about high-tech and AI that are coming as these vehicles are becoming more and more autonomous, adding to the competitive risks for Canada to miss out on this transition.

Table 5 - Decarbonization strategy for road transport: objectives and action items

LIGHT-DUTY VEHICLES	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Confirm alignment with rest of G7 (all but USA) to impose that all new light-duty vehicles must be zero emission by 2035 (with potential exceptions for remote areas)	Promote the emergence of Canadian players for parts, charging stations, and increase local manufacturing from foreign companies	2035: Use the progress on the ZEV mandate to position Canada as highly competitive for some subsectors on zero-emission light-duty vehicles, while giving access to low-cost vehicles to Canadians
Action items	1. Confirm a new schedule keeping all new light-duty vehicles zero emission by 2035 2. Develop and deploy a communication strategy to support ZEV 3. Prioritize the creation of a national network of charging stations 4. Impose pressure on manufacturers, with a possible schedule for partial lifting of duties on Chinese-made ZEV to lower prices/make appropriate vehicles available 5. Link ZEV compliance to industrial policy	1. Identify and remove of regulatory barriers/hurdles to ZEV deployment (mostly regarding charging) 2. Support and structure service industry (charging stations) through procurement (such as Circuit électrique) 3. Promote development and implementation of policies for recycling/reusing used EV batteries 4. Develop and implement policies for requalifying auto mechanics 5. Maintain pressure on prices to ensure international competitiveness for EVs 6. Create economical and regulatory environments to support automation and self-driving technologies, as well as the development of second hand markets	
HEAVY-DUTY VEHICLES - LOCAL	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Set horizon for zero-emission heavy-duty vehicles for local uses (trips of <200-300 km) for 2035/2040, in line with other countries.	Advance the deployment of ZEV in this category; structure a strong Canadian ecosystem (manufacturing, service)	2035-2040: All new vehicles are zero-emission for this sector which supports the creation a robust and export-competitive service and supply chain industry
Action items	1. Identify barriers and advantages for each segment: availability, charging infrastructure, price, presence of competing providers 2. Develop regulation enforcing ZEV mandate 3. Identify potential Canadian providers - products and services 4. Identify key potential innovations critical to this transformation	1. Use public sector procurement to support new technologies, local production and increase competitiveness; adopt ZEV mandate for this sector 2. Remove regulatory barriers to the deployment of ZEV 3. Adopt appropriate regulation for charging, safety, etc. 4. Adopt strategic, predictable and sustained procurement and subsidies to lower cost 5. Create economical and regulatory environments to support automation and self-driving technologies	

Table 5 - Decarbonization strategy for road transport: objectives and action items (continued)

LONG-DISTANCE FREIGHT	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Set a 2040-2045 horizon for zero-emission long-distance freight (> 400 km per day) to start orienting investments and deployment	Start deployment of ZE long-range freight demonstration lines; structure Canadian manufacturing, assembly and service industry	2040-2045: All new vehicles are zero-emission for this sector which supports the creation of a robust and export-competitive service and supply chain industry
Action items	1. Evaluate the potential technologies, taking into account other transformations (including self-driving) 2. Identify potential Canadian providers - products and services 3. Develop strategic procurement planning to support those providers 4. Start planning scalable pilot projects	1. Adopt ZEV mandate for this sector 2. Identify and remove regulatory barriers to deployment of ZEV 3. Create regulatory sandboxes to facilitate pilot projects 4. Adopt appropriate regulation for charging, safety, etc.. 5. Adopt strategic, predictable and sustained procurement and subsidies to lower cost 6. Create economical and regulatory environments to support automation and self-driving technologies	

3.3 Industry

Industrial GHG emissions can be divided into those coming from the combustion of energy for heat production (Figure 9) and those emitted by industrial processes, which result from chemical reactions linked to material transformation (Figure 10).

This sector includes heavy industries such as cement, steel and aluminum, as well as mining, manufacturing and food processing,[7] but excludes all energy production. A decarbonization strategy for industry would benefit from clear roadmaps for each industrial sector, to assess which measures to deploy over the coming decade and beyond. These should pay particular attention to process emissions, which require substantial innovation to be reduced at all.

Emissions in these sectors have been relatively flat since 2009. In total, they represent about 15% of all Canadian GHG emissions.

3.3.1 The size of the gap

Figure 9 shows that the measures under development could in theory make a difference resulting in almost half of combustion-related emissions being eliminated by 2030. Yet these projections in the AM scenario are based on extremely optimistic assumptions for projects currently on the table, which mainly include those funded by the Strategic Investment Fund and Net-Zero Accelerator, and high hydrogen adoption rates. These measures face limits after their initial impact, however, and emissions in the AM scenario bounce back before 2035.

To reach the 2035 reference target:

- 95% of fossil fuel energy used in heat processes would have to be decarbonized within 10 years, across industrial sectors, and
- All provinces would have to adopt the appropriate regulations to prevent the use of fossil fuels providing heat to industrial systems, and
- If electricity is used, national electricity baseload would need to be increased by an additional 25-30 GW (+10-15 percent of Canada's current capacity)[8] to support the electrification of heat (less if using heat pumps).

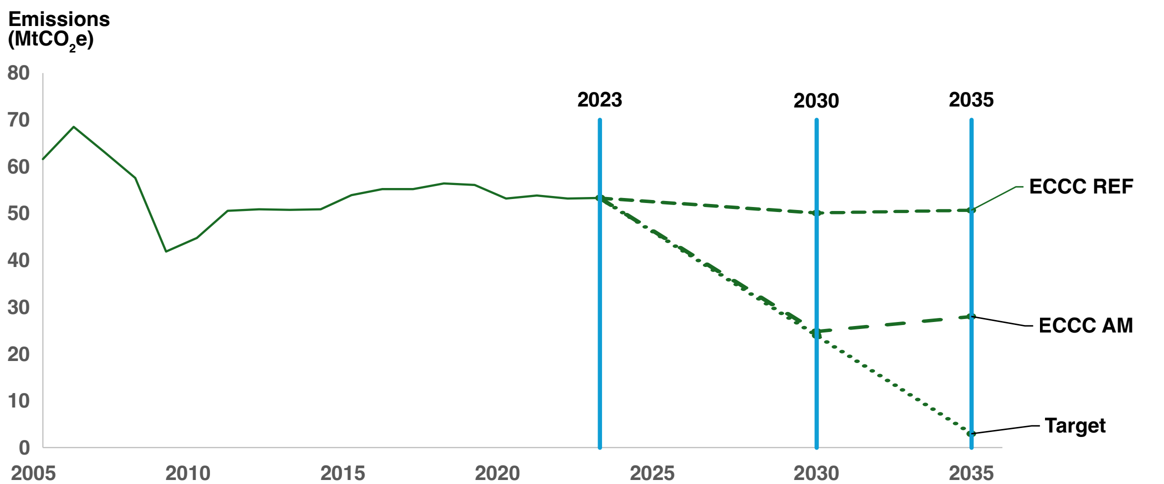
This implies that measures resulting in more lasting transformations, in particular targeting industry subsectors not affected by measures already under development, would need to be rapidly assessed to decarbonize heat production.

Table 6 - GHG emissions from industry (excluding oil and gas).

Sector	2005 ($ktCO_2e$)	2023 ($ktCO_2e$)	Percentage of total emissions In 2023
Heat	61,600	53,300	7.7%
Processes	57,000	51,700	7.4%
Total	118,600	105,000	15.1%

Source: ECCC (2025)

Figure 9 - Historical and projected GHG emissions from energy combustion in industry (excluding oil and gas)



Note: additional measures (AM) scenario includes, notably, some Strategic Innovation Fund/Net-Zero Accelerator (SIF/NZA) funding for CCS and energy efficiency projects, and hydrogen adoption based on anticipated domestic production

[7] While emissions due to the use of heat in agriculture is sometimes grouped with the industry sector, we exclude it here and treat it separately, as part of the agricultural sector in Section 3.5.

[8] Canada's Energy Futures 2021 Fact Sheet: Electricity, Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050 – Data Supplement, Canada Energy Regulator (https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023-data-supplement/)

3.3.2 Further implications of closing the gap

GHG reduction possibilities in the industry sector must be analyzed with care, as each subsector faces unique challenges. Even at an aggregate level, however, one aspect to keep in mind is that decarbonizing heat will require other energy sources and vectors — electricity, biomass, blue & green hydrogen and CCS as well as heat production technologies (heat pumps, infrared, etc.). All those mean regional planning for new supply and services would be required. Given the significant differences between heat and process emission sources, we suggest a strategy for each.

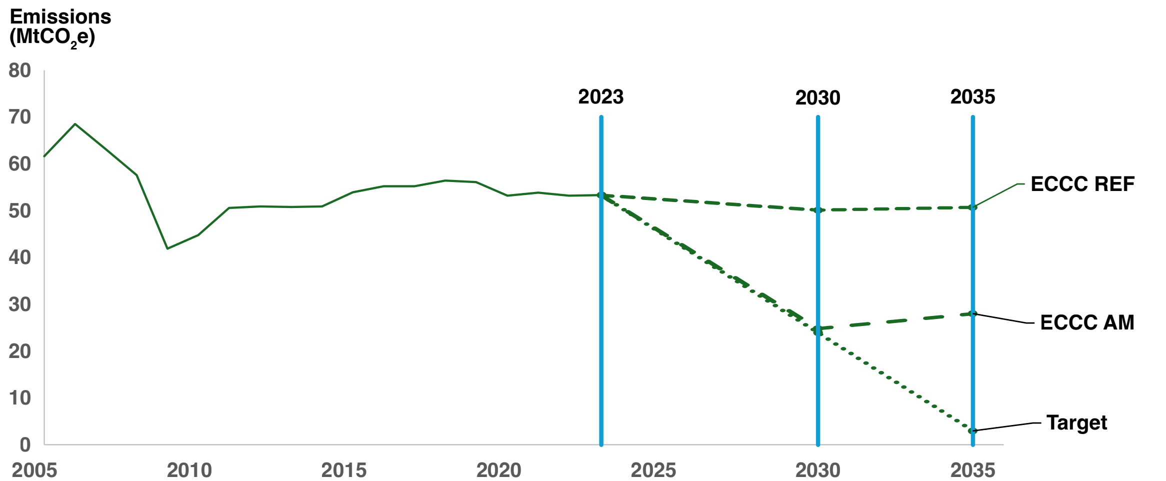
3.3.3 Heat

Industrial heat represents about 8% of national emissions. Industrial needs for heat vary in terms of power and temperature. Challenges for decarbonization are largely dependent on the temperature required: industrial heat pumps are ideal for needs of up to 200°C while higher temperatures are best provided with electric arcs, microwaves or bio-sourced energy.

To be cost-competitive, a heat pump cannot simply substitute for a gas furnace. To fully realize the potential of this technology, production processes must be redesigned to optimize the use and reuse of heat, moving heat from places that need to be cooled and concentrating it for processes that require high temperatures.

Redrawing the flow of heat and cold in a plant has the added benefit of optimizing the total energy use as well as improving control over production processes. Successful deployment therefore requires individualized mapping and design that integrate a sufficiently precise knowledge of the processes and the technical specification of the various heat pumps, an expertise that is largely absent in Canada today. At present industrial heat pumps are rare, not only in Canada but around the world, with most installations to date almost artisanal.

Figure 10 - Historical and projected GHG emissions from industrial processes (non-energy emissions)



Strategic interest for Canada

At the moment, decarbonization of heat in industry is still not widely deployed anywhere in the world due to the limits of the electricity production. If we act today, Canada could establish a strong supply and service industry, able to export its knowledge in the design, assembly, installation and maintenance of these infrastructures.[9] Moreover, there is a strong overlap between these services, especially for low- and medium-temperature production, and those for heating commercial, institutional and multi-unit residential buildings. Since energy demand for industry is more constant throughout the year, the overall costs of electrifying heat in industry are lower for the electric grid than for building heating.

[9] Other parts of the world are moving fast, though. For example, the Push2heat project, in Europe, aims to *address the technical, economic, and regulatory barriers that prevent heat upgrading technologies to be widely deployed* in the temperature range 90 °C to 160 °C.

What net-zero transformation looks like: key elements of an improved system

Decarbonizing heat through electrification requires a number of technologies. While the basic components are available, standard solutions such as those found for residential equipment do not exist: industrial heat pumps, for instance, are currently assembled to meet specific needs, increasing costs and risks of failure; similarly higher-temperature electric equipment is not always available off-the-shelf. Standardization requires the creation of sufficiently large markets, and for this to occur, strategic deployment across the various sectors must be supported by governments.

Physical changes needed to get there

There is a significant need to structure a service industry able to conceive, install and manage industrial heat pumps to decrease costs and reduce risks.

Given the diverse specifications for industrial heat, building a service industry requires specific strategies aimed at industrial and manufacturing subsectors with similar needs, such as food processing, drying, etc. The electricity infrastructure to support those, often installed away from the large cities, is similar. To succeed, it is therefore necessary to (i) develop subsector-specific strategies linked to heat production technologies in alignment with other sectors (agriculture, building, etc.); (ii) support increased production of electricity and the upgrade of the transport and distribution grids for the industries ahead of the transition; (iii) support the creation of a service industry able to lower technological risks while leveraging the transformation to increase productivity.

Key barriers to overcome

Each subsector, as a function of the technical challenge, should develop its own pathway to net-zero, with initial subsidies to support the structuring of the supply chain, through insurance or funding to suppliers coupled with price targets. To guarantee visibility for the suppliers, these efforts must be accompanied by some regulatory measures establishing the transformation rate for the whole sector.

For low-temperature heat (below 200°C), decarbonizing heat, in industry (as in agriculture), requires several components to be adjusted or provided, including:

1. Regulations reviewed to adapt requirements, for example for space in the service room, in training and for who can handle heat pumps, and
2. Plans developed for subsectors, but coordinated with plans for decarbonizing building heat, in order to:
   - **a)** impose a decarbonization schedule
   - **b)** leverage public spending to support innovation and the creation of a service ecosystem
   - **c)** guarantee the creation of a market, that will convince service providers to invest in training and in developing a solid supply chain
   - **d)** support early adopters, with a view to create knowledge on the service side, with subsidies to the installer or insurance companies, in a strategy to drive prices down
   - **e)** impose the decarbonization of sectors or regions, facilitating the creation of a service industry
3. Electric utilities that upgrade their networks to deliver the power and energy needed; here also, a strategic plan can orient the investment schedule to reduce costs and accelerate the electrification of industrial heat.

A specific strategy must be deployed for **high-temperature processes**, due to the need to assess, develop and de-risk specific technologies, including:

1. Testing technologies for specific industries
2. Integrating a biomass strategy
3. Supporting innovation and market creation, with clear objectives for each subsector
4. Designing and implementing subsector-specific regulation to impose decarbonization (here, it might be possible to combine subsector and regional strategies)
5. Using strategic financing to target the creation of an efficient supply chain and service industry and drive costs down to parity with current fossil-fuel technologies
6. Starting with sectors that are easier to integrate
7. Revamping the design of regulation for heating, which tends to favour natural gas.

More detail is found in Table 7.

Economic benefits to be captured

While the basic components of commercial and industrial heat pumps are mainly produced in Asia, there are intellectual property opportunities in the planning, the installation, the service and the supporting software to manage the complex flow of cold and heat in industrial sectors. If Canada moves sufficiently fast, it could be able to position itself as a world leader. This window will not last long, however, as other countries are moving more steadily to achieve their climate goals.

3.3.4 Processes

The decarbonization of industrial processes is more challenging and requires a wider range of solutions than heat. In most cases, long-established chemical processes must be rethought and fundamentally transformed to chemical pathways that do not involve the emission of CO_2. While, for many processes, alternative pathways exist and are often currently tested, they tend to be expensive or difficult to deploy except in particular cases[10].

Given this, decarbonizing process emissions can largely be done in two ways:

1. Replacing the established processes, or
2. Carbon capture and sequestration.

With regard to the replacement of established processes, efforts are already underway around the world to test and deploy low-carbon processes to replace current approaches. To maintain competitiveness, it is essential that Canada deploys a strategy to ensure that its industries are part of these efforts and identifies those that can find a local anchor to facilitate an early positioning in the development of the support industry. This strategy would entail: (i) identifying and pilot-testing promising low-carbon processes to replace those currently used, which would likely be happening in collaboration with international partners to reduce technological and competitive risks, and accelerating uptake; (ii) adopting sector-specific emission objectives to leverage specific technologies; (iii) creating a service industry able to accompany the transformation, with a focus on innovation for Canada. Given the specifications of each sector, however, these will not be covered here.

We focus instead on carbon capture and sequestration. Recent projections suggest that large-scale CO_2 capture and sequestration (CCS), including biochar, of up to 160 $MtCO_2e$ annually, is essential for Canada to achieve carbon neutrality.[11] According to these projections, CO_2 will be used both to sequester concentrated industrial CO_2 emissions and to compensate for distributed emissions, in agriculture, for example, through negative emission technologies.

The creation of such an infrastructure on a national scale calls for tackling at least three major challenges: (i) significantly increasing the rate of CO_2 capture; (ii) reducing the energy costs associated with capture and sequestration; and (iii) validating sequestration resources and techniques.[12]

Strategic interest for Canada

The challenges associated with CCS are numerous, but Canada has three significant advantages: a promising geology, large-scale low-carbon energy and a rich oil industry that will need to significantly reduce its GHG emissions if it is to remain globally competitive. Building on those, there exists a real possibility for Canada to establish itself as a world leader in this field.

[10] Harvey, J. (2024)
[11] Langlois-Bertrand *et al.* (2024)
[12] Mousseau and Langlois-Bertrand (2025)

What net-zero transformation looks like: key elements of an improved system

The various components of CCS involve a broad range of industrial sectors. These include the chemical sector, to produce compounds that serve to fix CO_2 or transform biomass, the construction sector to build the industrial infrastructure, the pipeline and drilling sectors, and much more. As each of these industries should also aim to be carbon-neutral, additional partners will be needed to provide clean energy and associated technologies.

Physical changes needed to get there

The contribution of CCS to the decarbonization of industrial processes should be focused on creating a large-scale new negative-emission industry based on carbon capture and sequestration: (i) support large-scale pilot projects to decrease risks, optimize CCS and negative-emission technologies based on biomass and direct-air capture; (ii) leverage the oil and gas sector to deploy first commercial CCS with high-capture rates (> 90 to 95% net capture of GHG); (iii) develop technology and regulation to support negative-emission commercial deployment; (iv) proactively explore and assess geological CO_2 storage capacity.

Key barriers to overcome

Enabling factors are necessary at multiple levels, to promote investments, to support innovation, to secure intellectual property, to reduce short- and long-term risks associated with geological storage and to rapidly move to scale.

More specifically:

1. Bring the oil and gas industry, through regulation or carbon pricing, to invest the billions promised in the deployment of large-scale CCS infrastructure
2. Support the construction of large-scale CCS and negative-emission pilot projects, including biochar production and utilization to establish the real potential of these technologies, to drive prices down, and to scale up CCS. The public funds currently available are largely insufficient. Publicly financed projects should not be limited to (or even necessarily prioritize) the oil and gas sector.
3. Directly pursue assessments of geological risks associated with carbon sequestration
4. Support the creation of this new industry through:
   - **a)** Clear and predictable regulation and carbon pricing through integration with international markets; in particular, actively contribute to the emergence of the offset market now enshrined in the Paris Agreement, to leverage internationally available funds
   - **b)** Work with provinces to ensure the design and implementation of regulations in all provinces with the appropriate structure to ensure the safety of carbon sequestration
   - **c)** The use of strategic financing to target the creation of an efficient supply chain and service industry and to drive costs down
   - **d)** Efforts to ensure Canadian ownership of the intellectual property
   - **e)** Support for the use of CCS and negative emissions beyond the oil and gas sector

Economic benefits to be captured

With considerable structural and geological advantages, in addition to a large potential for clean energy, Canada could establish itself as the leader in the CCS technologies and manufacturing, as well as bring in investments from around the world, especially with direct air capture technologies to also provide capture and sequestration services for industries from around the world.

For the remainder of this section, we briefly review the gap between the evolution of the GHG emissions in each remaining sector and Canada's objectives in order to better understand the full scale of the challenges faced by Canada. A deeper analysis of trajectories able to reach net zero will be presented in the near future. We also give special attention to electricity provision as a key overarching challenge related to all sectors.

Table 7 - Decarbonization strategy for industry: objectives and action items

LOW-TEMPARTURE HEAT	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Send a clear signal that low-temperature heat will have to be decarbonized across manufacturing and industrial sectors by 2040; launch a deployment strategy	Create a service and supply industry by ensuring a market; aim at reducing risks and prices	By 2040: Achieve decarbonization of low-temperature heat across all industrial and manufacturing sectors; create a robust and export-competitive service and supply chain industry
Action items	1. Identify first-adoption sectors (such as agro-food industry) based on the existence of regional clusters, electric capacity, and support industry 2 . Identify regulatory barriers to the use of heat pumps and start process to lift them 3. Draw subsector specific decarbonization strategies and schedules to structure the market 4. Develop regulation for preventing deployment of natural gas low-temperature heating for new industries and furnace replacements	1. Support the deployment of electric infrastructure to facilitate extended electrification 2. Implement programs to favour the deployment of a service industry, including lowering prices and accelerating deployments 3. Identify and support innovation in the service and supply chain sector 4. Use public sector procurement to support new technologies, local production and increase competitiveness	
HIGH-TEMPERATURE HEAT	**Short term (1-12 months)**	**Medium term (1-5 years)**	**Long term (5-25 years)**
Objectives	Send a clear signal that high-temperature heat will have to be decarbonized by 2050; launch a research and pilot strategy	Identify technologies for a large fraction of the needs; start strategic deployment	By 2050: Achieve decarbonization of high-temperature heat across all industrial and manufacturing sectors; create a robust and export-competitive service and supply chain industry for certain high-temperature technologies and sectors
Action items	1. Identify early adopters 2. Identify regulatory barriers to the use of high-temp low-carbon solutions and start process to lift them 3. Draw a general schedule and strategies for the decarbonization of high-temperature heat 4. Identify key technologies with their state of development	1. Draw subsector-specific decarbonization strategies and objectives to structure the market 2. Deploy a strategy to develop a supply and service industry for the various technologies, with support for increasing their competitiveness 3. Support the deployment of electric infrastructure to facilitate extended electrification 4. Use public sector procurement to support new technologies, local production and increase competitiveness 5. Strengthen carbon pricing for large industrial emitters	

Table 7 - Decarbonization strategy for industry: objectives and action items (continued)

CCS	Short term (1-12 months)	Medium term (1-5 years)	Long term (5-25 years)
Objectives	Send a clear signal that Canada aims to be a central actor in large-scale CCS: both innovation and deployment	Through successful large-scale pilot projects, start the deployment of industrial CCS sites across Canada, led by Canadian businesses	By 2050: Bring Canada and other nations to net-zero with the support of CCS; having made Canada one of the two or three world leaders in this field.
Action items	1. Strengthen industrial carbon-pricing markets to force commitments from large emitters regarding CCS, including biomass projects (comes with objectives) 2. Set up programs to support large-scale pilot projects integrated with a real-life large-scale deployment (not only oil and gas) 3. Support geological work to develop appropriate safety regulations regarding carbon storage and improved mapping of storage potential 4. Develop a strategy to secure Canadian intellectual property and knowledge and support the growth of Canadian world leaders 5. Lead an international effort to develop an international market for carbon removal (offset)	1. Maintain the value of CCS through various tools (regulation, contracts for difference, etc.) 2. Develop and implement a strategy to strengthen Canadian industry supporting the CCS technologies and increase its competitiveness 3. Develop and implement a strategy to make Canada a world leader in CCS to the benefit of international actors (reinforcing benefits for Canada) 4. Build on this capacity to attract other industries to Canada 5. Establish a credible plan for long-term sustainability of carbon storage facilities	
PROCESSES	**Short term (1-12 months)**	**Medium term (1-5 years)**	**Long term (5-25 years)**
Objectives	Signal clearly that Canada understands the economic benefits of supporting the decarbonization of processes	Become a world-leader in the development and test of a few critical technologies for processes	By 2050: Ensure that Canadian Industrial processes are fully decarbonized
Action items	1. Develop a specific blueprint to decarbonize processes in industry, first through processes change, second through CCS 2. Identify a few technologies and industries where Canada has a competitive advantage	1. Adopt subsectoral decarbonization objectives to support industrial efforts 2. Support large-scale pilot projects linked to full-scale deployment in Canada	

3.4 Oil and natural gas production

Oil and natural gas extraction and transformation is now the main source of Canada's emissions, reaching 30% of the total. While the carbon intensity of this production has diminished over the past decade, this has not been enough to compensate for increased production and to bring emissions down even from their 2005 level. Production expansion in the next few years, should it occur, would remain the main driver of emissions from the sector.

Two key measures are the basis for reductions expected in ECCC's additional measures scenario: (i) more stringent methane requirements, which represent a key source of further emission reductions; and (ii) the full implementation of the proposed emissions cap regulation, which sets the cap at 27% under 2026 reported emissions. According to the AM scenario, these two measures would deliver a 27% reduction from 2023 levels, almost all of which would occur before 2030; without both these measures, ECCC's reference scenario expects emissions to remain at more or less the same level as today (Figure 11).

3.4.1 The size of the gap

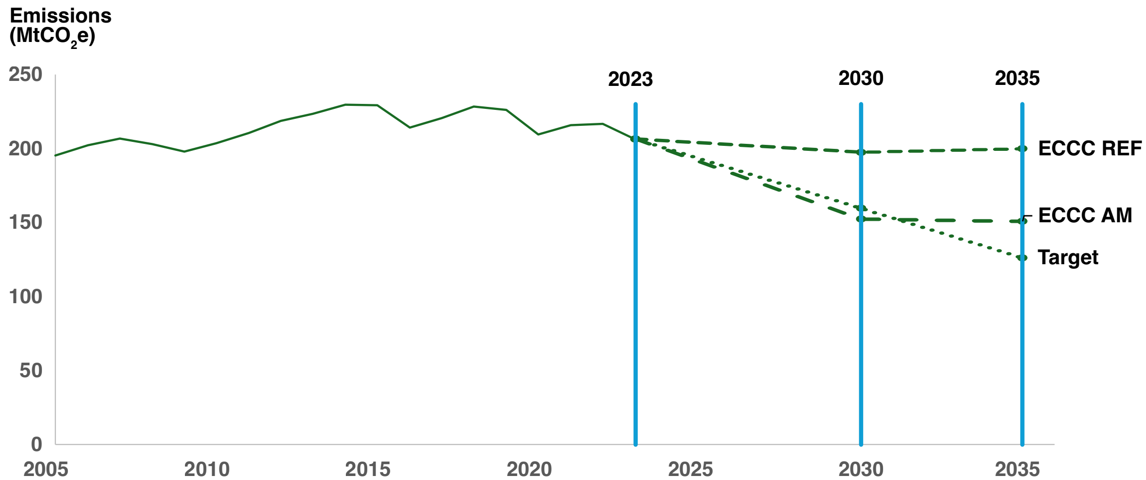
ECCC projections clearly show that without additional measures, no reductions are expected from the sector before 2035. Given the size of oil and gas production emissions, this makes it all but certain that Canada would miss its national reduction targets. On the one hand, **this underlines the importance of the measures currently under discussion, notably the oil and gas emissions cap and additional methane regulations**.

On the other hand, there remains significant political opposition to these measures, and **assuming their full implementation in just a few years is optimistic at best**.

To reach targets:

- additional methane requirements would need to be implemented and validated on the ground
- a 27% reduction in the net emissions for oil and gas production would also be required, through production reduction, carbon capture and sequestration or the use of clean energy for a large part of heat production in oil sands.

Figure 11 - Historical and projected GHG emissions from oil and natural gas extraction and transformation



Note: additional measures (AM) scenario includes, notably, an oil and gas emissions cap and strengthened methane regulations

3.4.2 Further implications of closing the gap

In order to meet any interim GHG reduction targets on the 2050 horizon, it must be kept in mind that **not substantially reducing oil and gas emissions means a much deeper reduction would be needed in all other sectors**, which are already facing the difficulties outlined in this document. Unlocking the solution(s) to reducing a large portion of emissions from the oil and gas sector thus remains a challenge that would need to be met.

The sector's contribution to the country's overall GHG mitigation strategy could be enhanced in several ways. For instance, using carbon capture and storage more extensively within the sector could provide a way to smooth the fundamental transformation of the sector in a pathway compatible with net-zero in 2050. However, **at the moment, it is very difficult to see how CCS can be economically viable, unless costs fall significantly through a stronger national carbon market or a solid international negative-emission market**. In addition to these economic tools, if carbon capture and storage is to be used in the oil and gas sector, it would also need to be tested at scale and deployed rapidly, with leverage, potentially, from other emitting sectors.

3.5 Agriculture

Emissions associated with agriculture come mainly from non-energy-related sources (notably soils, enteric fermentation and manure management). To a lesser extent, some energy-related emissions occur in the sector, mainly for heat production and vehicles and machinery. **Emissions from the sector have been some of the most difficult to reduce so far**, due to a combination of challenges: first, the bulk of emissions from the sector (79%) come from agricultural processes, implying that emissions mitigation would require transformations to current dominant practices or reductions in agricultural production; second, the rest of emissions come from energy-related operations and, as such, they present a host of challenges with regard to the main decarbonization strategies used in some other sectors, notably electrification.

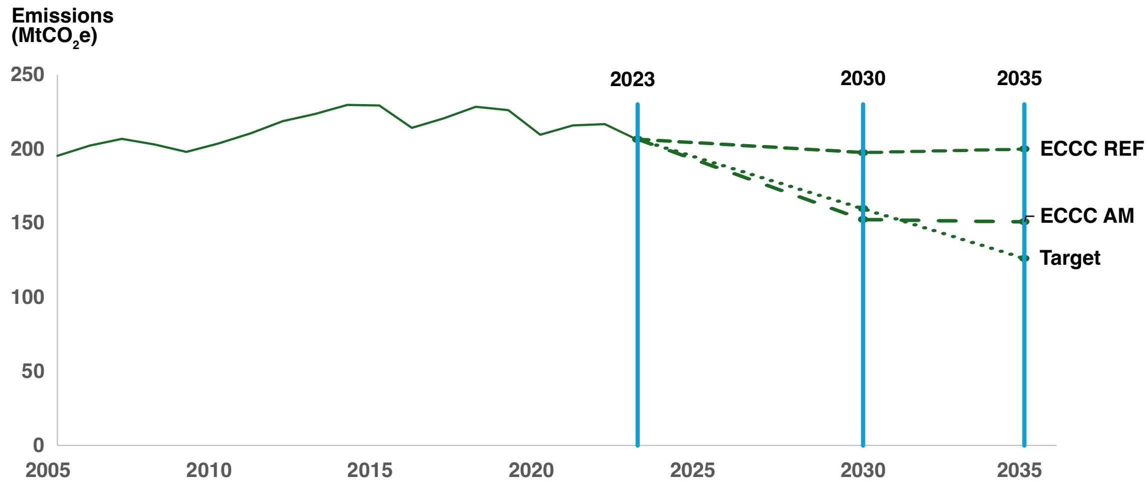
Partly as a result of these challenges, very limited reductions have occurred recently in this sector and none are expected in ECCC's reference scenario. Measures under consideration included in the additional measures (AM) scenario include mainly a fertilizer emissions reduction target of –30% below 2020 levels by 2030, resulting in a more sizeable reduction before 2030 after which emissions go back up (Figure 12). No other measures targeting agriculture are included in the AM scenario.

3.5.1 The size of the gap

To curb agricultural emissions, the limited attention given to the decarbonization of agriculture would need to be rapidly corrected for transformations to begin. In the absence of additional measures, few transformations are expected. Projections highlight the limited impact of fertilizer reduction targets, but also that no transformation in practices to reduce emissions from enteric fermentation or soil management is expected.

As for equipment, there are no dominant low-carbon technologies currently beginning to replace emitting ones. This is true for stationary equipment as for off-road agricultural vehicles and machinery, as costs remain very high and availability is limited across the country. Furthermore, the decarbonization of equipment requires a steady supply of low-carbon energy, be it electricity, hydrogen or even sustainable liquid fuels, which requires the deployment of new energy distribution infrastructure.

Figure 12 - Historical and projected GHG emissions from agriculture



Note: additional measures (AM) scenario includes a fertilizer emissions reduction target

Bringing down reductions in the agricultural sector in line with other sectors (to help reach the -50% by 2035 target) would therefore make it necessary to :

- Decarbonize all fuel use in the sector (21% of total emissions)
- Reduce by a third emissions from crop and animal production (79% of emissions)

3.5.2 Further implications of closing the gap

As for industry, separate strategies are needed for heat, farm machinery and processes to procure access to low-carbon energy and associated technologies. For heat generation, one of the challenges of using low-carbon equipment is that the much larger power needs are very unevenly distributed throughout the year: drying crops, for instance, requires a considerable amount of heat but only for a very limited period, which complicates the economics of using a low-carbon form of energy that requires fixed distribution infrastructure onsite. For farm machinery, the significant infrastructure needs to distribute electricity or low-carbon fuels to agricultural sites, the range of vehicles and hours of operations, and more generally the cost of existing low-carbon equipment, remain significant constraints which contribute to a reluctance for large-scale transformations to vehicle fleets. Therefore, policy measures to address both heat and machinery decarbonization should take into account locational constraints and potential advantages: where grid capacity exists nearby, for instance, additional infrastructure to provide power needs for charging may be more economical and would need to be explored; in more remote areas or where grid capacity is constrained, a more comprehensive assessment of available options is necessary, and pilot projects should be launched early on to narrow down and better assess these options.

A strategy to decarbonize agricultural processes requires a roadmap and subsequent planning of how to scale up some known lower-emission practices. There are several approaches available, for instance reducing fertilizer use further, regenerative agriculture, or organic agriculture, each with its own environmental benefits and drawbacks. However, solutions are strongly dependent on the specific conditions under which a local sector operates, including what crops or livestock the operation produces (fruit, grain, beef, eggs, vegetables, etc.).

Developing an impactful national strategy is therefore challenging and requires planning, testing and data gathering as soon as possible. This remains one of the areas where the policy reflection is underdeveloped, making this source of emissions very likely to grow considerably in importance over the next few decades.

3.6 Waste

Waste-related emissions include those from landfills (85.7%), wastewater treatment and discharge (11.4%), municipal composting (2.2%) and waste incineration (0.6%). Despite the existence of economic options to reduce a large part of these emissions, their deployment has been unequal across the country and national emissions have stagnated since 2008 despite some strategies deployed to reduce them, notably biogas capture or energy generation from municipal solid waste transformation.

Policy measures currently in place are at the provincial level, notably in British Columbia (95% organic waste diversion target for 2030), Ontario (circular economy strategy with a 50% waste diversion goal by 2030), Quebec (70% organic waste diversion by 2030 and landfill methane regulation), Manitoba (financial incentives for organic waste processing) and Newfoundland and Labrador (50% diversion goal by 2025 and reduction of open burning and incineration).

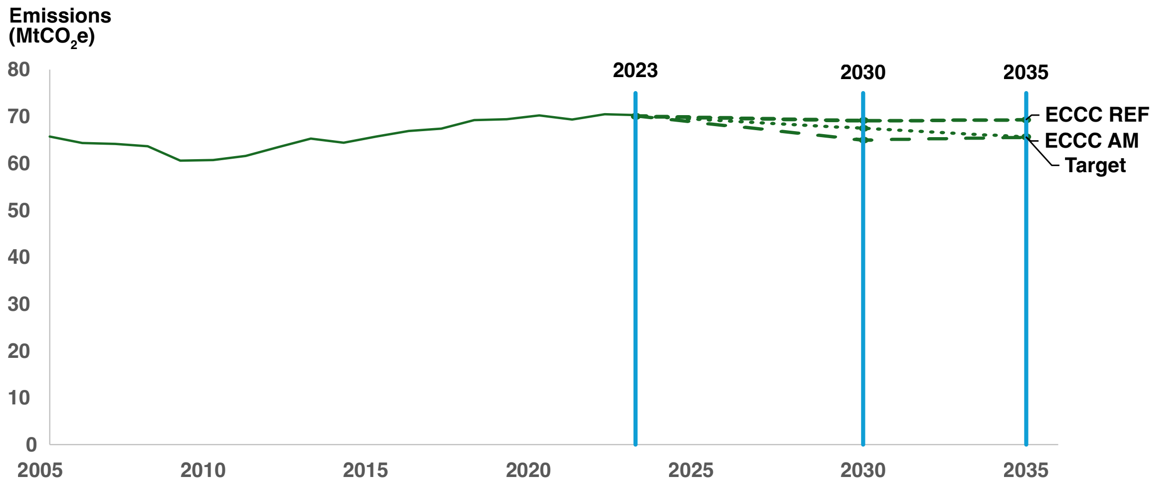
3.6.1 The size of the gap

ECCC's current measures scenario projects a relatively limited impact of measures to divert organic waste. The three largest provinces all have significant diversion goals that are assumed to be met before 2035, and emissions are still projected to increase from today's levels. The proposed federal Regulations Respecting the Reduction in the Release of Methane, which aims to increase landfill gas capture beginning in 2027 and at rates reaching 39% to 79% depending on the province, make the AM scenario achieve a sizeable reduction before 2030 (around 40% from today's level). However, even achieving these objectives would leave over 60% of today's emissions from waste and no further measure is planned.

3.6.2 Further implications of closing the gap

As for other sectors, reducing waste emissions further requires more than simply intensifying current approaches. As the main waste emission reduction strategies have been deployed at a larger scale over the past few years, some contradictions have emerged in uncoordinated approaches in the same region. For instance, organic waste diversion aiming to maximize composting may achieve a certain level of reduction, with the compost by-product; but by doing so, it reduces biogas capture potential in landfills, since these hold less organic waste as a result of this diversion. Reversing the priorities would not eliminate this contradiction.

Figure 13 - Historical and projected GHG emissions from waste



Note: additional measures (AM) scenario includes federal landfill gas regulations

A coordinated strategy could resolve these contradictions, taking advantage of the fact that most strategies so far are associated with a valuable by-product (compost fertilizer and biomethane, in the example above). Therefore, the approach should take into account these by-products to maximize the value of the organic resources. This requires a careful consideration of the technical difficulties in realizing the transformation (for instance, some processes are significantly affected by the purity of the matter digested, or some regions struggle to make use of the compost produced in municipal facilities), which in turn affect the value of the energy product obtained. Moreover, maximizing the contribution of these choices to the regional net-zero pathway requires situating the by-product in broader biomass use planning.

3.7 Electricity production

In all net-zero pathways modelled for Canada, **electrification is the main decarbonization tool**: this supposes a significant expansion to current grids, built ahead of energy needs for sectors. The capacity increase required even within the next five years is considerable: from 5% to 20% in additional generation capacity (depending on the province) as well as a replacement of emitting sources. Taking this at face value, then, means considerable new generation capacity must be built rapidly across all provinces. Yet, these modelling exercises grossly underestimate the electricity needs (Mousseau and Langlois Bertrand, 2025).

Over the past 20 years, the electricity sector has seen its emissions decrease substantially, largely as a result of the phase-out of coal-fired generation in Ontario and by the replacement or conversion of coal-fired generation to natural gas in Alberta. Continuing this trend is more challenging, as provinces relying on thermal generation often have little other baseload capacity (Alberta, Saskatchewan, Nova Scotia and New Brunswick, in particular). Reducing these emissions substantially to realize ECCC's 2035 projections (REF and AM numbers are similar for 2035 at 18 and 14 $MtCO_2e$ left in 2035, respectively, given the assumed implementation of the CER) would therefore require an effective strategy to ensure that reliability and resilience remain high to maintain the services provided to the population by these grids.

3.7.1 The size of the gap

Meeting these expansion needs implies very considerable investments in infrastructure, similar to what was seen between 1970 and 1990, but well beyond the recent historical levels for most utilities across the country. Moreover, while capacity expansions and thermal generation replacement attract a lot of attention in the debate over deploying the infrastructure to support the decarbonization of sectors through electrification, this is a rather incomplete picture of the transformations needed. Adding generation capacity that will occur in new sites and from more land-intensive sources like wind and solar means upgrading the electricity transmission capacity in all provinces, and ideally across provinces as well taking advantage of more integrated grids. Furthermore, most distribution grids are in dire need of maintenance and upgrading as well, given the densification of demand that occurs through electrification. In other words, assessing the investment costs and logistics of expanding grid capacity means taking into account significant costs beyond those of new generation facilities. Hydro-Quebec, for instance, has evaluated its total needs at $185 billion between 2023 and 2035, in order to add around 30% of production capacity and upgrade transmission and distribution grids across the province.

If the amount of investment needed to realize this on the short term is significant, it will deliver considerable savings as well: replacing fossil fuels with electricity for many services generally results in the use of equipment that is both more energy efficient and more productive. Nevertheless, building a grid equipped to support decarbonization across sectors must be done very rapidly, especially for provinces where electricity provides only a small share of energy services today. As a result, the planning of the deployment must be completed urgently in provinces where it has yet to occur, so that funds can be secured and construction can begin.

Overall, the main gap here is linked to increasing clean electricity production and delivery to meet the demands of the various sectors. This requires:

- Increasing total electricity production by about 40-50% between now and 2035 and the power capacity of the grid by 60-70% (see next section)
- Strengthening transport and distribution infrastructure to accommodate customer needs

3.7.2 Further implications of closing the gap

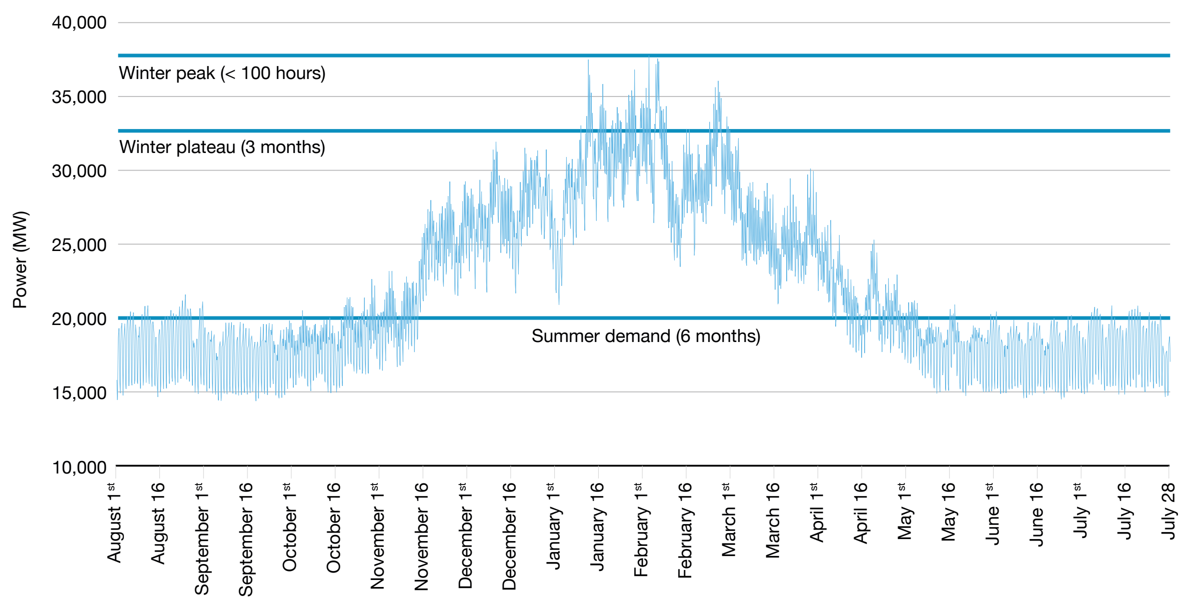
Decarbonizing sectors through electrification, implies a transformation of electricity's role in the energy mix well beyond the absolute capacity increase described above. Some of the key services to be electrified, discussed in other sections of this report and expected to deliver GHG reductions, will contribute to a shift in the demand pattern that adds further complications to this grid expansion. Above all, the electrification of space heating in residential and commercial buildings (see Section 3.1) and, to a lesser but not insignificant degree, the electrification of transport will add strains through a considerable exacerbation of peak demand in the winter, unless these peaks are actively managed and reduced through various technological and policy options (Edom and Mousseau 2023; 2025).

Figure 14 shows the demand pattern for Quebec, the province that currently has the largest share of electrified building heating. As the Figure shows, this level of electrification leads to a winter demand plateau where demand is over 50% higher for two or three months than during the rest of the year, in addition to a small number of hours during the winter where temperatures are coldest and demand spikes 20% above the winter plateau average. Without careful management of these periods, the risk of cost increases resulting from the need to build capacity just to supply these periods but with no use for the rest of the year is very high.

In the very short term, therefore, the electrification of services requires a very rapid buildout of electric capacity and a handling of grid congestion in regions where electricity provides fewer services at the moment. For instance, in regions where natural gas provides virtually all residential space heating, space heating and personal transport electrification can come first from concentrated geographical clusters like wealthier neighbourhoods: given the limited capacity of the local distribution grid, this electrification can rapidly lead to a bottleneck that must be resolved by grid upgrades, thereby ensuring that electrification is not slowed down or that social inequities around decarbonization are not amplified.

Finally, it should be noted that the discussion above focuses on 2035: the task of electrifying services in net-zero pathways goes well beyond needs to be met before 2035, and in fact is even more substantial on the longer-term. The planning and rollout of infrastructure over the next few years will therefore need to be done in a way that facilitates learning from experience and leads to adjustments in the planning of the subsequent buildout.

Figure 14 - Two-year average power demand in Quebec (2021-2022 and 2022-2023)



Source: Mousseau and Langlois-Bertrand (2025)

4 Conclusion

While other countries are transforming their economy on the way to net-zero, Canada is falling behind, missing its targets and, more importantly, missing on the technological and economic opportunities offered by an electricity-based revolution.

For Canada to benefit from this revolution and maintain competitiveness, it needs to revise its current strategy and to adopt a sector-based approach focused first and foremost on low-carbon technological transformations instead of simply counting emissions.

The strategies presented in this report offer a starting point for the discussion of how to realize this goal.

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