ONTARIO ENERGY BOARD

EB-2024-0342

IN THE MATTER OF the *Ontario Energy Board Act*, 1998, S. O. 1998, c. 15, Schedule B;

AND IN THE MATTER OF an application by Enbridge Gas Ins. for approval to construct gas works in an expanded area in Tay Valley Township

AFFIDAVIT OF SUSAN BRANDUM

I, SUSAN BRANDUM, of the Township of Drummond/North Elmsley, in the Province of Ontario, hereby AFFIRM:

1. I am the Co-Founder of Climate Network Lanark ("CNL") and a current member of its board. Because of that role, I have knowledge of the information contained in this affidavit. Where I refer to information from others, I state the source of the information, and I believe all such information to be true.

Overview

2. My affidavit describes the following:

   a. The expanded approval to construct gas pipelines that Enbridge seeks is inconsistent with both the Tay Valley Township and Lanark County Climate Action Plans. Also, those plans are consistent with established decarbonization science and research.

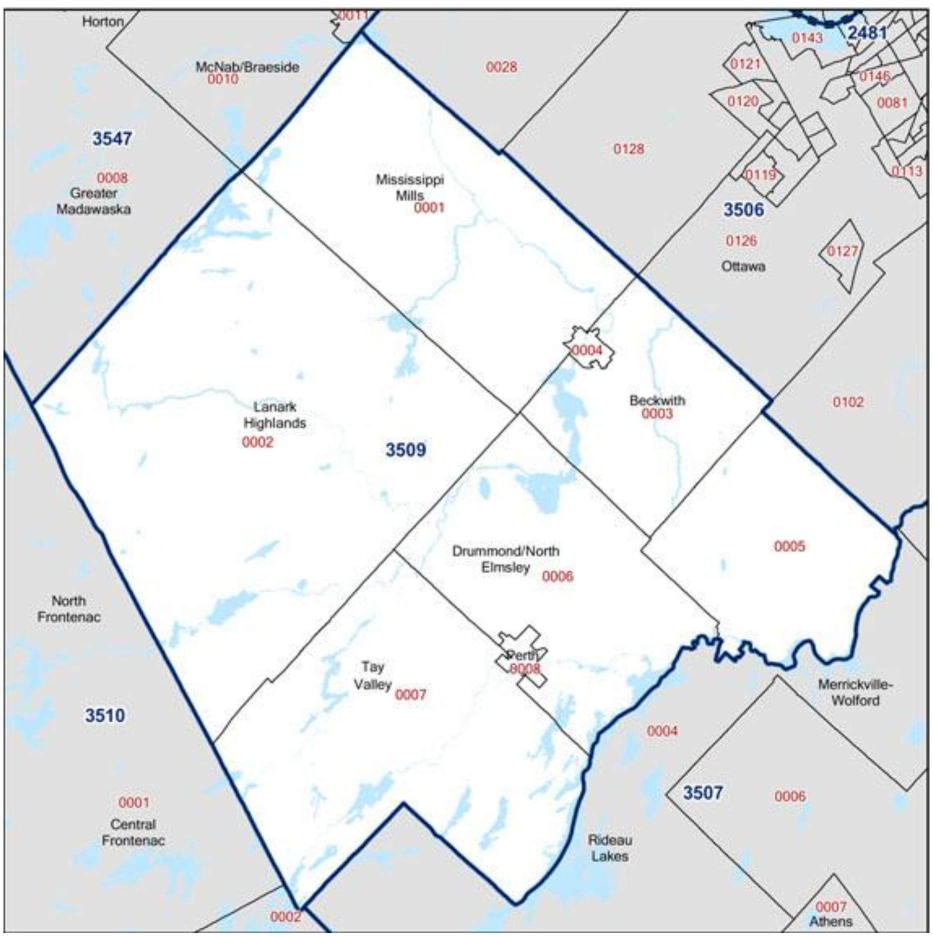
   b. The expanded approvals are inconsistent with local opposition to fossil fuels by residents of Tay Valley Township and Lanark County.

   c. Granting the expanded approvals to Enbridge is contrary to the interests of residents because of Enbridge's deceptive marketing and focus on fossil fuels.

   d. There is no need for any entity to be granted the expanded approvals.

3. I have more than 40 years of experience in the energy and environmental sectors. I co-founded CNL in 2019 and have assisted the organization in a variety of capacities since that time. I am currently a director of the organization and remain actively involved in its programming. I was also the General Manager of Rideau Environmental Action League ("REAL") for approximately 20 years. In both of those roles I have helped design and deliver programming that assist homeowners to reduce the energy costs and carbon emissions from their homes through energy efficiency. In the 1980s and 1990s I was a journalist and writer focusing on energy and environmental issues.

4. For twenty-five years, my work on energy and environmental issues has been based in Lanark Country and focused on the needs of the residents of Lanark County, including those in Tay Valley Township. A map of Lanark County and its constituent municipalities obtained from Statistics Canada is shown below.



Inconsistent with climate action plans

5. Expanded approvals to construct fossil fuel pipelines in a wider area in Tay Valley Township is inconsistent with the climate action plans for Tay Valley Township and Lanark County.

6. The Climate Action Plan for Tay Valley Township is attached to and discussed in the affidavit of Noelle Reeve. I agree with comments and facts laid out by Ms. Reeve in her affidavit and I believe them to be true.

7. The Climate Action Plan for Lanark County is attached as **Exhibit "A"** to my affidavit. The second guiding principle in the Climate Action Plan for Lanark County is to "eliminate fossil fuels." The expanded fossil fuel pipeline construction approvals sought by Enbridge are inconsistent with this for the same reason they are inconsistent with the Tay Valley Township Climate Action Plan, as outlined in Ms. Reeve's affidavit.

8. The Lanark County Climate Action Plan outlines the likely impacts of climate change on the County (on page 10), which are comparatively higher than the global average because warming is expected to occur at higher rates in northern areas. The Plan also includes carbon emissions reduction targets, which are illustrated below.

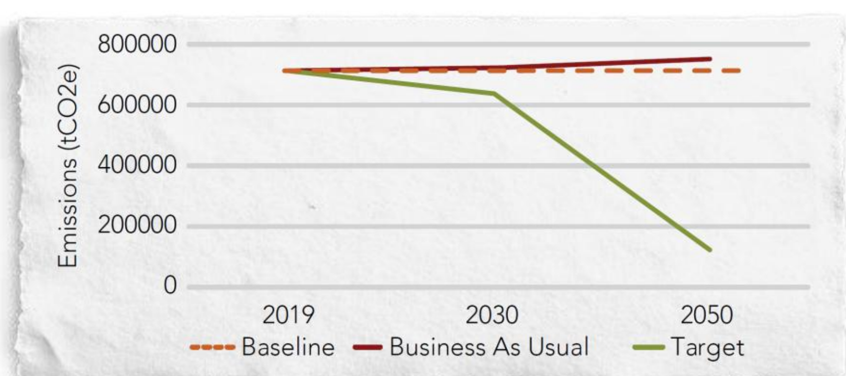


Figure 9. Community greenhouse gas emissions under different scenarios (baseline, business as usual, emission reduction targets).

9. If carbon emissions are meant to decline according to the Plan's target, it makes no sense to grant approvals to construct fossil fuel infrastructure in new areas of the County,

particularly when the construction would occur long into the future and at a time when our carbon emissions must be even lower.

10. The portions of the Climate Action Plans calling for an end to the combustion of fossil fuels are consistent with the latest science and research on decarbonization. I have attached a report by energy experts prepared for the Ontario Ministry of Energy entitled *Cost Effective Energy Pathways Study for Ontario* as **Exhibit "B."** This report describes how the most cost-effective pathway to decarbonize Ontario involves electrification of buildings. I have also attached a report prepared by energy experts for the Canadian Climate Institute as **Exhibit "C."** This report reaches the same conclusion for Canada and for Ontario. Both reports find a minimal or no role for gas pipelines in the most cost-effective pathways to achieve net-zero by 2050. I believe the facts and conclusions set out in these reports and in the Climate Action Plans of Tay Valley Township and Lanark County to be true.

Inconsistent with civil society values

11. Civil society in Lanark County is strong and active with respect to energy and climate issues. This includes the work and the supporters of the Climate Network Lanark. The people and organizations that exist locally are much more active than one would expect for a county of this size.

12. Non-profits and volunteer groups in our area are active in a variety of ways with respect to energy and the environment. This includes the delivery of energy savings programs and initiatives to combat climate change. For examples of some of the work that the Climate Network Lanark has undertaken, please see my affidavit of April 22, 2025.

13. Local residents have also been involved in local demonstrations against the continued combustion of fossil fuels. Some photos from local demonstrations are attached as **Exhibit "D"**. The issue also comes up in public meetings. For example, I made a comment in a public meeting about a planned residential development, stating that it should not be heated by fossil fuels like gas. The comment received strong applause from all present, with many standing up to applaud and voice their support.

14. In this way, the request for expanded fossil fuel construction approval in a wider area is inconsistent with local support for the climate and against fossil fuels.

Inconsistent with resident interests

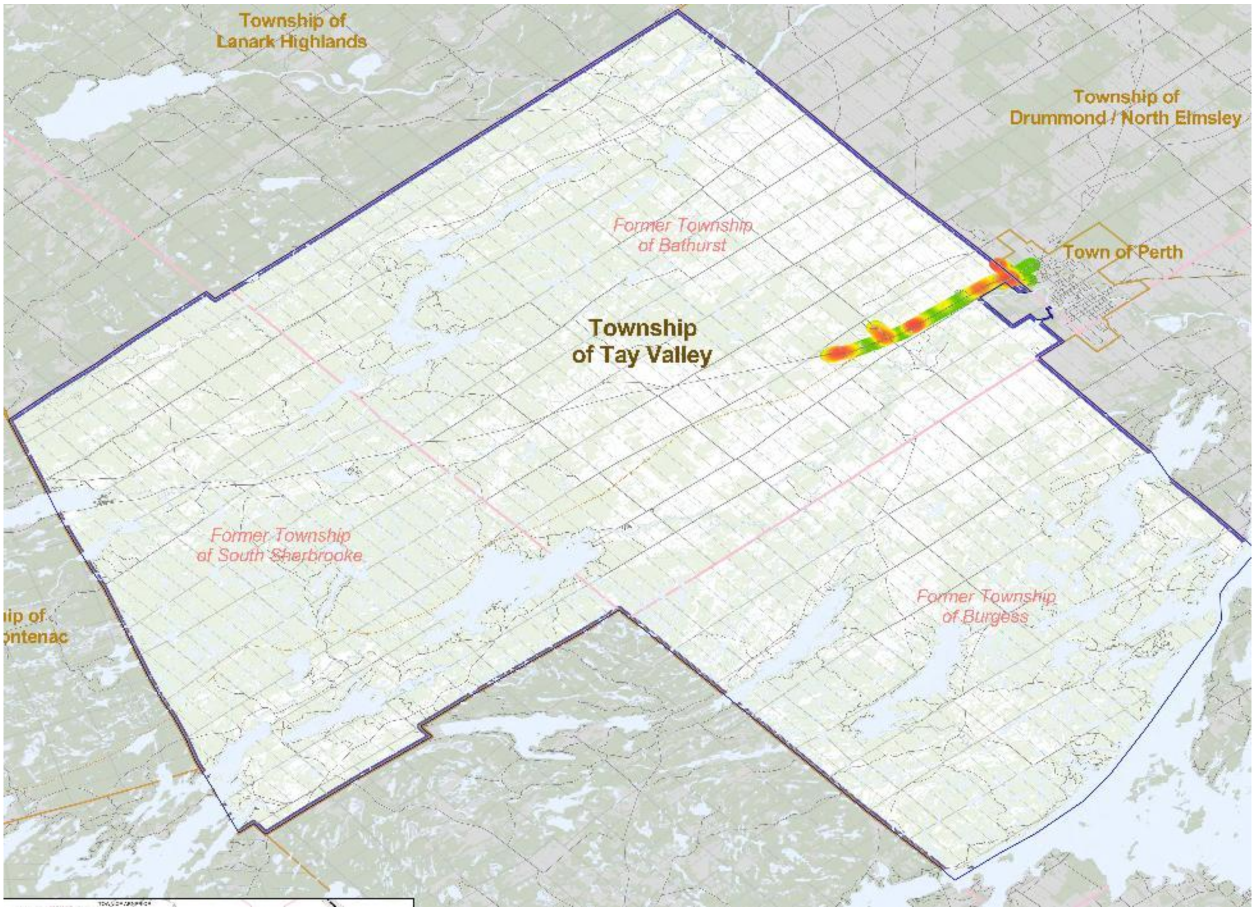
15. There are also specific and important concerns about Enbridge being the company that is granted a monopoly over a larger area, including Enbridge's deceptive marketing and its focus on fossil fuels.

16. The Climate Network Lanark was one of six organizations that joined together to request a formal inquiry be instituted against Enbridge Gas for deceptive marketing under the *Competition Act*. That application, along with the declaration of the Chair of the Climate Network Lanark are attached as **Exhibit "E."** I believe the facts set out in that application to be true. As a result of our application, the Commissioner of Competition commenced an inquiry, which is still ongoing. It is not in the interests of residents to grant an expanded monopoly to a company that deceives potential customers.

17. I also do not believe the residents of the Township or County would be best served by Enbridge because it is so heavily focused on fossil fuels. That is contrary to our residents' environmental and financial interests.

Not necessary

18. There is no need to extend Enbridge's approval to construct gas infrastructure to the former townships of South Sherbrooke and North Burgess. The map Enbridge provided shows that the existing gas pipeline is far from both of those former townships. That map is shown below.



19. Also, the Lanark gas expansion that Enbridge is considering does not bring pipelines any closer to those former townships. The latest version of Enbridge's plans that I am aware of would have the new pipeline run northwest along Highway 511, which is on the border of Tay Valley Township and the Township of Drummond / North Elmsley. That is the opposite direction from the former township of North Burgess.

Conclusion

20. No approval should be granted to construct fossil fuel pipelines in expanded areas within Tay Valley Township. The Township and the County need to cut our fossil fuel use and greenhouse gas emissions. Enbridge's request is not consistent with the kind of world that we want to pass on to our grandchildren.

AFFIRMED REMOTELY BY video conference by Susan Brandum stated as being at the Township of Drummond/North Elmsley, Province of Ontario, before me in the City of Toronto, Province of Ontario on this 25th day of July 2025, in accordance with O. Reg. 431/20, Administering Oath or Declaration Remotely.	)))))))))

Susan Brandum

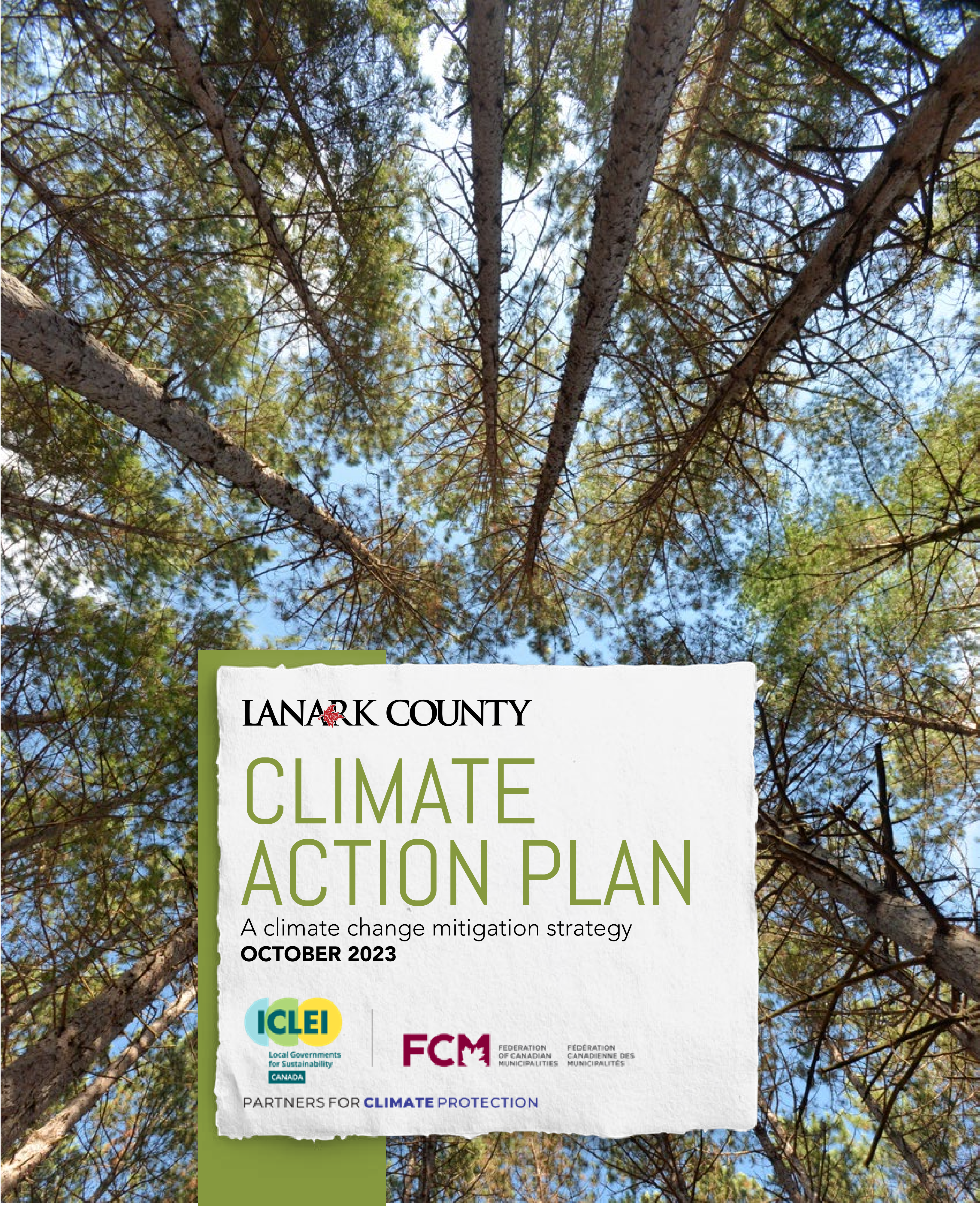
Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C

SUSAN BRANDUM

This is **Exhibit A** referred to in the affidavit of Susan Brandum
sworn or affirmed before me on July 25, 2025.

____

Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C



LANARK COUNTY

CLIMATE ACTION PLAN

A climate change mitigation strategy

OCTOBER 2023

ICLEI Local Governments for Sustainability CANADA

FCM FEDERATION OF CANADIAN MUNICIPALITIES FÉDÉRATION CANADIENNE DES MUNICIPALITÉS

PARTNERS FOR **CLIMATE** PROTECTION

LETTER FROM THE CAO

Dear Lanark County residents,

In recent years, climate change has become increasingly visible in Lanark County and across the globe. The impacts are being felt close to home as we experience long-lasting heat waves, the destruction of severe thunderstorms, powerful ice storms, and unprecedented wildfire seasons.These extreme weather events put strain on our infrastructure, economy, and environment, and have serious consequences for the livelihood of our community members.

On behalf of Lanark County staff, I am pleased to present the Lanark County Climate Action Plan. This plan was created in collaboration with our local municipalities, community stakeholders, and community members, and led by County Council. Many great ideas, insights, discussions, and fields of knowledge were brought forward to help build this plan. I look forward to continuing to learn how we can best respond to the evolving climate with advancements in innovation and technologies.

With extreme weather events becoming more common, the County of Lanark recognizes the urgent need to reduce our greenhouse gas emissions, prepare for climate change impacts, and become a regional leader in climate action. The Climate Action Plan outlines the goals and strategies Lanark County will take to reduce the climate impact of our buildings, transportation, waste, and land use, while also providing opportunities for local climate action. This is no small task, and the challenges of climate change can be overwhelming. However, with the continued support of our local municipalities, councillors, staff, and community members, we are eager to begin implementing the goals within this plan.

To see a meaningful reduction in greenhouse gas emissions, municipalities must act. Lanark County is committed to empowering its citizens and providing resources to learn, improve, and adapt to the climate crisis. I look forward to overseeing the implementation of this plan and participating as an individual in Lanark County.

Sincerely,

Kurt Greaves

ACKNOWLEDGEMENTS

2021-2022 Climate Action Committee Members

John Fenik Chair *(June 2021 to February 2022), Town of Perth*
Rickey Minnille Chair *(February 2022 to November 2022), Mississippi Mills*
Susan Brandum ***Climate Network Lanark***
Gord Harrison ***Climate Network Lanark***
Richard Kidd ***Beckwith Township***
Ross Rankin ***Town of Carleton Place***
Paul Kehoe ***Drummond/North Elmsley Township***
Jeannie Kelso ***Lanark Highlands***
Tony Hendriks ***Town of Perth***
Shawn Pankow ***Town of Smiths Falls***
Bob Argue ***Tay Valley Township***
Kathryn Maton ***Mississippi Mills***
Klaas Van Der Meer ***Montague Township***
Michelle Rabbetts ***Lanark County***
Kurt Greaves ***Lanark County***
Jasmin Ralph ***Lanark County***

2023 Climate Action Working Group Members

Toby Randell ***Chair, Town of Carleton Place***
Judy Brown ***Town of Perth***
Rickey Minnille ***Mississippi Mills***
Rob Rainer ***Tay Valley Township***
Elizabeth Gallant ***Lanark County***
Kurt Greaves ***Lanark County***
Jasmin Ralph ***Lanark County***

Community representatives from Climate Network Lanark, Smiths Falls, and each of the local municipalities are included as needed dependent on the topic and scope of items discussed.

Report Authors

Elizabeth Gallant ***Lanark County***
Madeline Seward ***Lanark County***
Michelle Rabbetts ***Lanark County***

We would like to acknowledge all local municipalities, community members, Climate Network Lanark, Greenscale Incorporated, and Sustainable Kingston for their contributions to the development and preparation of the Lanark County Climate Action Plan, as well as Bob Argue for his contributions to the development of the Lanark County Climate Lens for all Council decisions. The collective knowledge and insight of all members was critical to developing a framework to reduce greenhouse gas emissions and reduce the impact of climate change in Lanark County.

EXECUTIVE SUMMARY

Collective action is required to address climate change. In 2019, Lanark County joined the Partners for Climate Protection (PCP) program and committed to acting on climate change through the creation and implementation of a climate action plan. The Lanark County Climate Action Plan provides an outline of goals aimed at achieving emission reductions while ensuring the resilience of our local communities.

Climate Change in Lanark County

The effects of climate change are becoming increasingly more prominent in Lanark County. Some impacts we can expect to see as a result of climate change include:

- *Heat and drought, impacting local water supply and agricultural practices*
- *More ice days, threatening safety and damaging infrastructure*
- *Damage to infrastructure, risking critical water, sanitary, and power systems*
- *Loss of native biodiversity, increasing the introduction of invasive species, pests, and disease*
- *Mental health challenges caused by climate change stressors*
- *Illness and disease due to increased heat stress and poor air quality*
- *Increase in zoonotic and vector borne diseases*
- *Disruptions to the economy as infrastructure and assets are threatened*
- *Soil erosion and nutrient loss, impacting local agricultural systems*
- *Increased risk of flooding and fire*

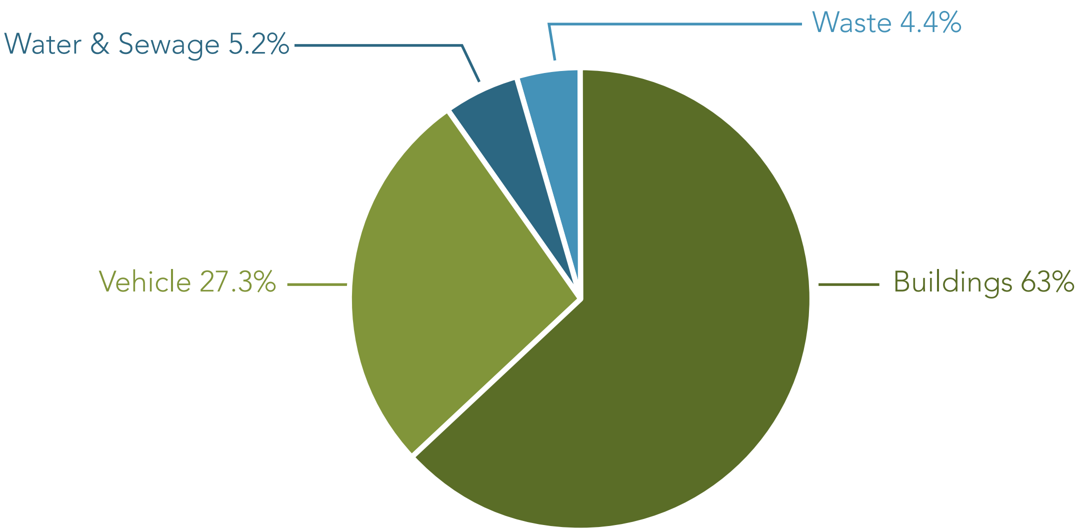
Guiding Principles

The Climate Action Committee developed a set of seven guiding principles to guide the development of the Lanark County Climate Action Plan. The guiding principles serve as the vision for the plan and provide a framework for current and future additions to the Climate Action Plan.

1. **Create a climate conscious culture and community**
2. **Eliminate fossil fuels**
3. **Optimize energy/water efficiency and increase renewable energy generation**
4. **Advance the use of nature-based solutions in climate change management**
5. **Sustainably manage waste towards a circular economy**
6. **Collaborate with community stakeholders**
7. **Increase funding, accessibility, and education**

Corporate Climate Action Plan

In 2019, 2,462 tonnes of CO2e were emitted from Lanark County corporate operations. The two largest sources of corporate greenhouse gas emissions are County buildings and vehicles. Recognizing that different actions require varying levels of time, resources, and support, Lanark County set mid- and long-term corporate emission reduction targets of 25% below 2019 levels by 2030 and 80% below 2019 levels by 2050.

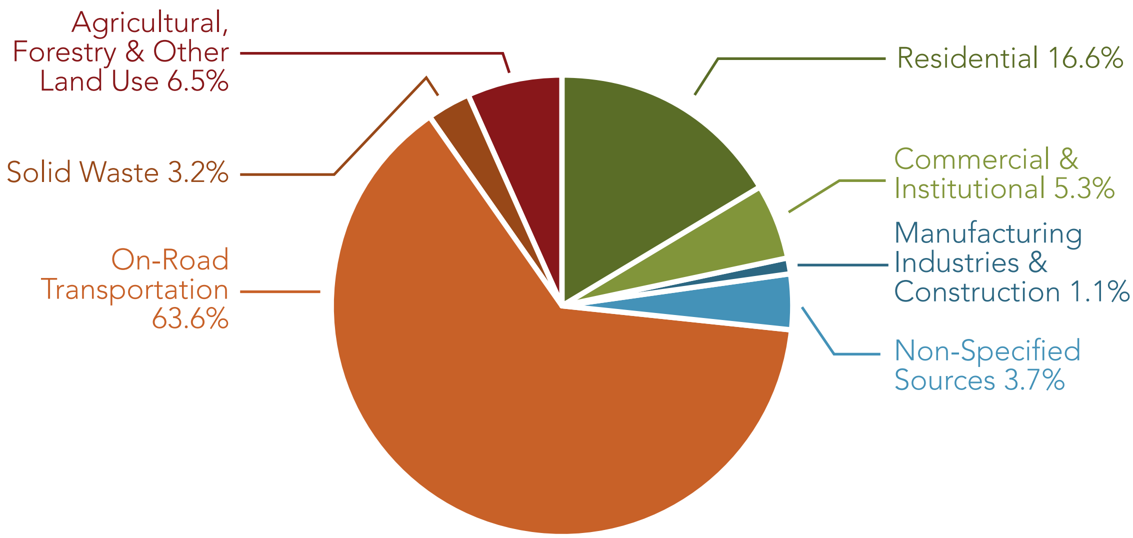


The Corporate Climate Action Plan has 29 goals that fall under the following 7 themes:

Theme	Summary of Goals
Education	Assessing the climate impact of Council decisions, raising staff awareness, and encouraging staff to reduce energy consumption in the office.
Buildings and energy	Improving and optimizing building efficiency and assessing opportunities to utilize renewable energy where possible.
Lanark County Housing Corporation	Assessing the efficiency of the Lanark County Housing Corporation building portfolio to reduce fossil fuel consumption and optimize energy efficiency where possible through deep retrofits, appliance upgrading, and renewable energy sources.
Natural heritage and resources	Protecting our natural heritage and resources that sequester carbon to maintain resiliency in the changing climate.
Transportation and equipment	Transitioning to electric fleet, increasing electric vehicle infrastructure at County buildings, and purchasing electric power tools and equipment.
Waste diversion and management	Reducing plastic waste and improving the corporation's waste diversion.
Planning	Planning for and acting on the anticipated impacts of climate change through plans and policy change.

Community Climate Action Plan

In 2019, 696,972 tonnes of CO2e were emitted from the Lanark County community as a whole. The two largest sources of community greenhouse gas emissions are on-road transportation and residential buildings. Recognizing that different actions require varying levels of time, resources, and support, Lanark County set mid- and long-term community emission reduction targets of 10% below 2019 levels by 2030 and 80% below 2019 levels by 2050.



The Community Climate Action Plan has 21 goals that fall under the following 5 themes:

Theme	Summary of Goals
Transportation	Transitioning to and promoting low carbon transportation through exploring low-carbon fuels, electric vehicles, active transportation, carpooling and rural transit options to reduce single occupancy vehicle trips.
Buildings and energy	Developing a home energy retrofit program, increasing energy/water retrofits in the industrial, commercial, and institutional sector.
Natural heritage and resources	Protecting our natural heritage and resources that sequester carbon to maintain resiliency in the changing climate.
Waste diversion and management	Identifying sustainable solid waste and recycling solutions and optimizing organic waste diversion.
Planning	Planning for and acting on the anticipated impacts of climate change through policy change.

Implementing the Climate Action Plan

Lanark County will adopt 6 main implementation strategies to successfully implement the Lanark County Climate Action Plan.

Leveraging funding

Building community partnerships

Increasing staff capacity

Institutionalizing climate action

Strategically prioritizing climate initiatives

Effectively engaging and educating community

To respond quickly and effectively to the climate crisis, Lanark County will prioritize 8 major climate initiatives for the current Council term (2023 – 2026).

1. *Support the adoption of electric vehicles*
2. *Transition to low-carbon transportation when electric is not a viable solution*
3. *Advance transportation demand management programming and infrastructure*
4. *Increase the use of local and renewable energy generation and security*
5. *Improve energy efficiency of existing buildings*
6. *Sequester carbon and protect natural resources*
7. *Optimize organic waste diversion*
8. *Create a climate conscious community culture*

Monitoring and Reporting

Progress of the Climate Action Plan will be reported regularly at the bimonthly meetings of the Climate Action Working Group. An annual progress report of the Climate Action Plan will be provided to County Council and made public at the end of each year.

The Climate Action Plan will be reviewed every two years which will include an inventory update and review of emission reduction targets. These reviews will provide an opportunity to adjust the plan through the addition of new goals and removal of those that have been completed. The update and revisions of this plan will ensure that the plan remains relevant with new information and advancements in technologies and continues to reflect the evolving needs of the community.

The Way Forward

Lanark County aims to identify ways to overcome the limitations presented to the climate action plan. Understanding the sequestration of carbon in Lanark County will help to improve the understanding of Lanark County's carbon footprint. In addition, taking Lanark County's geography and population into consideration when exploring initiatives will be an important component to selecting and implementing actions.

Reducing Lanark County's greenhouse gas emissions provides opportunities to improve the overall sustainability of our community. Many of the initiatives in the climate action plan provide not only benefits to our climate and environment, but also opportunities for social, cultural, and economic development. Engaging the Lanark County community to implement climate actions will be vital to achieving community reductions. Building partnerships with municipalities, businesses, organizations, schools, and individuals will be necessary to engage the community in a meaningful way.

Table of Contents

List of Acronyms

AD-CHP	Anaerobic digestion – combined heat and power
ALUS	Alternative Land Use Services
BAU	Business as usual
CAO	Chief Administrative Officer
CO2e	Carbon dioxide equivalent
EV	Electric vehicle
FCM	Federation of Canadian Municipalities
GHG	Greenhouse gas
GMF	Green Municipal Fund
ICLEI	International Council for Local Environmental Initiatives
IESO	Independent Electricity System Operator
KPI	Key performance indicator
LCHC	Lanark County Housing Corporation
LGLDHU	Lanark Leeds District Health Unit
MVCA	Mississippi Valley Conservation Authority
PCP	Partners for Climate Protection
RNG	Renewable Natural Gas
RVCA	Rideau Valley Conservation Authority
SCOP	Sustainable Communities Official Plan
SMART	Specific, measurable, attainable, realistic, time-bound

INTRODUCTION AND OVERVIEW

About Lanark County

Lanark County has a population of 75,760 and is located southwest of Ottawa on the traditional territory of the Omàmìwininìwag (Algonquin) (Figure 1). Lanark County is an upper-tier municipality comprised of eight thriving lower-tier municipalities: Lanark Highlands, Mississippi Mills, Carleton Place, Drummond North Elmsley, Perth, Tay Valley, Beckwith, Montague; and one separated town: Smiths Falls.

Lanark County has a rich geographic landscape. Situated on Precambrian and Paleozoic bedrock, Lanark County covers over 300,000 hectares of which nearly 58% is forested. Lanark County spans both the Rideau Valley and Mississippi Valley Watersheds and is home to over 100 lakes, rivers, and waterfalls, and at least 47 provincially significant wetlands[1]. This landscape supports a diversity of flora and fauna and provides the vast agricultural, recreational, economic, and social opportunities for which Lanark County is known.

Holding the title of the Maple Syrup Capital of Ontario, Lanark County is rich in history and rooted in traditions. The rural areas and quaint towns depict the heritage of this region through their preserved architecture and infrastructure.

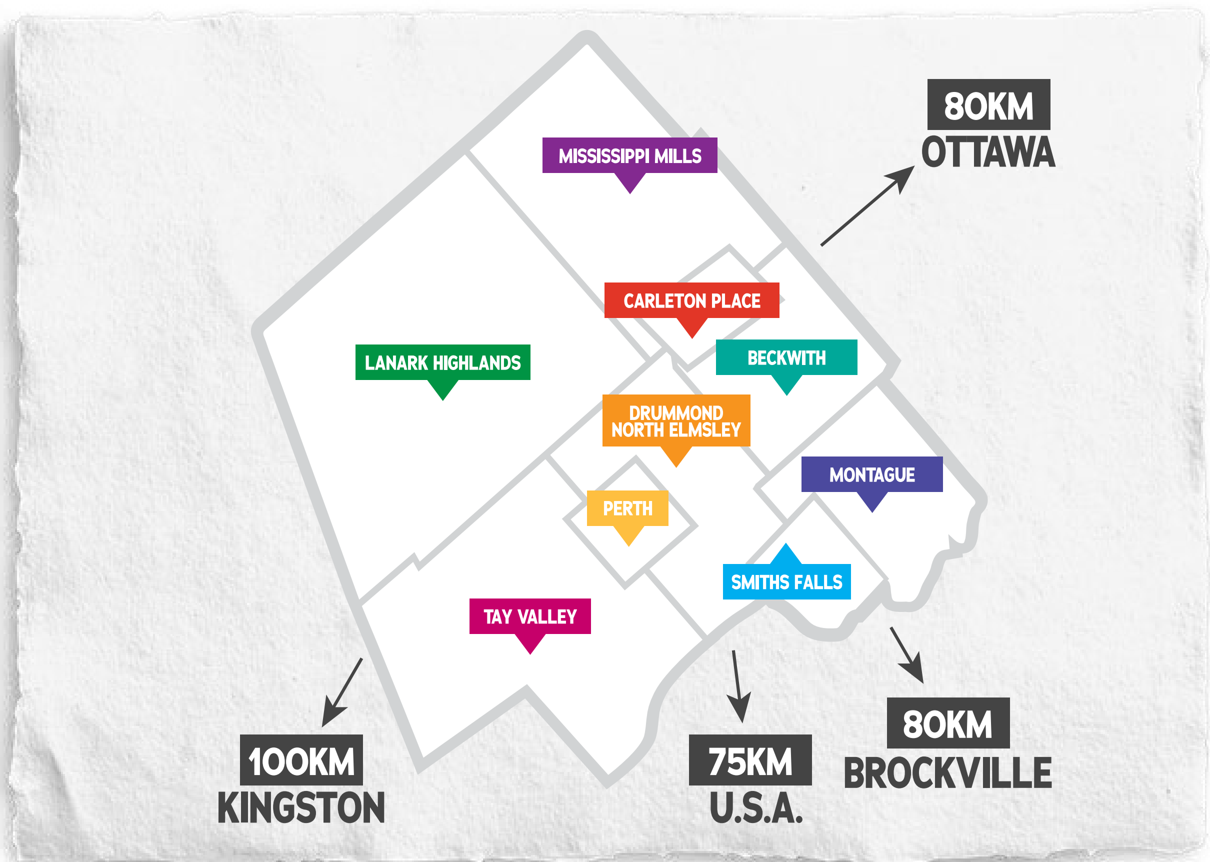


Figure 1. Map of Lanark County.

1 Keddy, P.A. (2008). Earth, Water, Fire: An Ecological Profile of Lanark County. Arnprior, Ontario: General Store Publishing House, p. Map 14

Lanark County's Climate Commitment

Climate change is a national and international issue. As part of the United Nations Framework Convention on Climate Change, Canada agreed to the principle of "common but differentiated responsibility and respective capabilities"[2]. This acknowledges the fact that developed countries have the greatest emissions intensities, while the greatest impacts of climate change are felt by developing countries. Centered around global equity, this principle means that developed countries, such as Canada, have a greater capacity to reduce their emissions, and thus share a moral responsibility to take the lead on climate change mitigation.

In Canada, municipal governments influence or control roughly half of the country's greenhouse gas emissions, meaning they are in a unique position to be leaders in climate change mitigation and adaptation initiatives[3]. Municipalities can use their regulatory power to effectively address climate change and greenhouse gas emissions through land-use planning, community energy planning, zoning, by-laws, grants, and funding opportunities. While municipal governments can play a strong role in climate leadership, all levels of government and community members will need to participate in climate action to see meaningful reductions in greenhouse gas emissions. The creation of the Lanark County Climate Action Plan provides the County, municipalities, and community members with methods to collectively create a more resilient community for the future.

Lanark County is dedicated to working collaboratively with its nine local municipalities to improve and support sustainability in the County. In 2012, Lanark County adopted its first Sustainable Communities Official Plan (SCOP) to integrate sustainable practices into land use policies. Lanark County identified climate change and air quality as a main theme of the SCOP; thus, the County committed to reducing greenhouse gas emissions and other air pollutants, while also planning for changes in the climate and natural environment. To achieve these commitments, Lanark County began the process of developing a Climate Action Plan with the Partners for Climate Protection (PCP) program in 2019.

2 United Nations. (1992). United Nations Framework Convention on Climate Change. Retrieved from https://unfccc.int/resource/docs/convkp/conveng.pdf **3** Federation of Canadian Municipalities. (n.d.). Climate and sustainability. Retrieved from https://fcm.ca/en/focus-areas/climate-and-sustainability

Partners for Climate Protection Program

The PCP program from ICLEI—Local Governments for Sustainability (ICLEI Canada) and the Federation of Canadian Municipalities assists municipalities in taking action against climate change by reducing municipal greenhouse gas emissions. The PCP program uses a five-step framework to guide municipalities towards carbon reductions:

MILESTONE 1: Creating a greenhouse gas emissions inventory and forecast.

Requirements for approval from PCP:

- *A summary of community and corporate inventory that follows the PCP Protocol*
- *Emission intensity values or coefficient values*
- *Summary of data sources*
- *Description of methodological assumptions, omissions, and other relevant data*
- *A 10-year business-as-usual emissions forecast*

MILESTONE 2: Setting an emissions reduction target.

Requirements for approval from PCP:

- *A description of targets, including baseline year, target year, and percentage change from baseline year*
- *A council resolution that adopts the targets set, including the baseline year, target year, and percentage change from baseline year*

MILESTONE 3: Developing a local action plan.

Requirements for approval from PCP:

- *Description of the activities that will help you achieve your target reductions*
- *Description of how the public or internal stakeholders participated in developing the plan*
- *Description of the costs and/or funding sources*
- *Names of the municipal departments and/or organization(s) responsible for the plan and the actions outlined in it*

MILESTONE 4: Implementing the local action plan.

Requirements for approval from PCP:

- *Description of the degree to which measures in your local action plan have been implemented (include implementation partners, financing mechanisms, and variations from the original plan)*
- *The implementation schedule*

MILESTONE 5: Monitoring progress and reporting results.

Requirements for approval from PCP:

- *An updated corporate or community inventory for the current (or near current) year*
- *Quantification of the GHG reduction impact of each measure outlined in your local action plan*
- *Report on how stakeholders and decision makers have been included through the milestone process*

The publication of the Lanark County Climate Action Plan marks the completion of Milestone 3 of the PCP program. The plan's primary objectives are to work with stakeholders to reduce greenhouse gas emissions within Lanark County, while also preparing the community for present and future changes. Lanark County is now in the process of implementing the Climate Action Plan, including corporate and community initiatives.

Climate Action Plan Development

The Lanark County Climate Action Plan is divided into two main sections: 1) the Corporate Climate Action Plan, which outlines how the County will address climate change and reduce greenhouse gas emissions from its municipal operations, and 2) the Community Climate Action Plan, which outlines how the County will address climate change and reduce greenhouse gas emissions from the community at large.

Since 2019, community representatives, municipal staff, and local organizations have worked together to develop the framework and set the trajectory of the Climate Action Plan (Figure 2). The Climate Action Committee was active from June 2021 to November 2022 and was made up of representatives from all lower-tier municipalities and the Town of Smiths Falls, Climate Network Lanark, and Lanark County. Together, the Climate Action Committee provided strategic direction for the development of Lanark County's Climate Action Plan and recommendations for climate action initiatives in Lanark County. The Climate Action Working Group emerged in February 2023 and will continue for the remainder of this Council term (2023-2026). The working group is made up of three elected officials from Lanark County Council, members of the Executive Management Team of the County, and Lanark County staff. Representatives from each lower-tier municipality, the Town of Smiths Falls, and Climate Network Lanark are included as needed dependent on the topic and scope of the item discussed. The Climate Action Working Group provides direction for the implementation and reporting of Lanark County's Climate Action Plan.

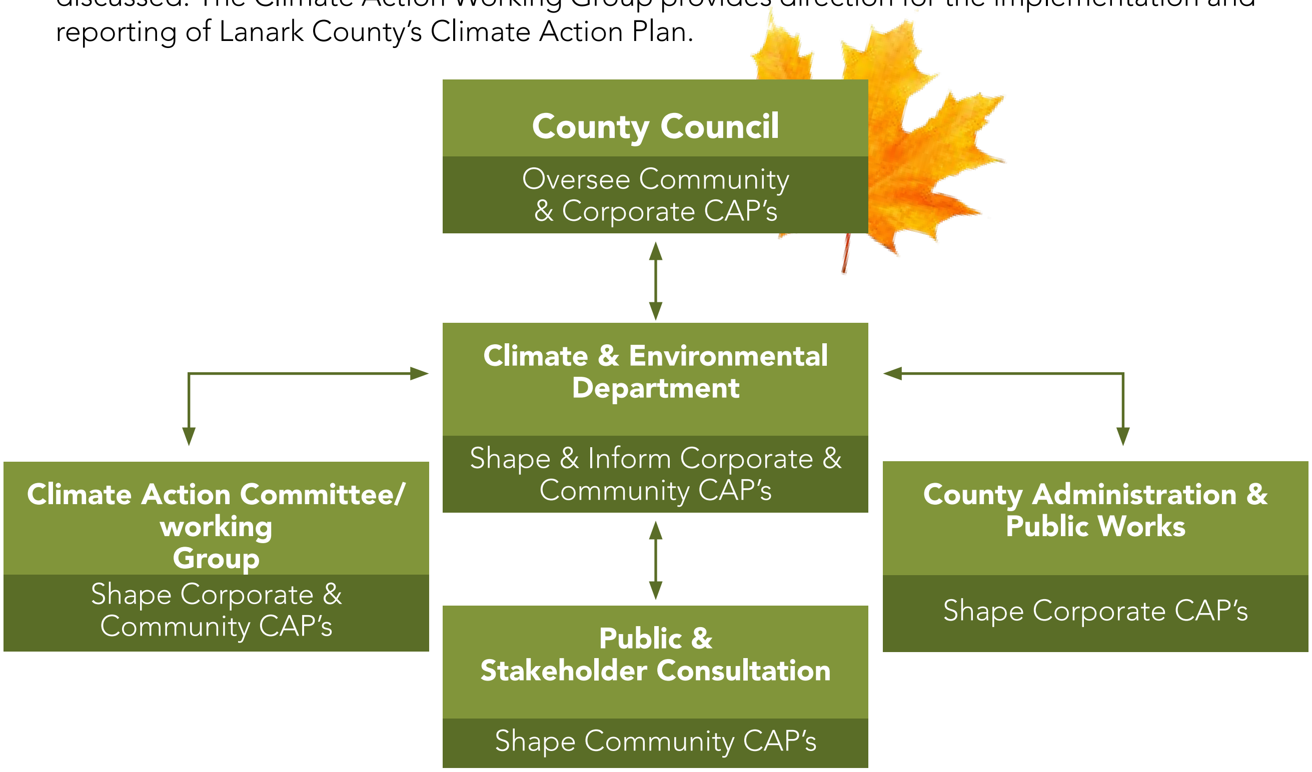


Figure 2. Collaborative structure of the corporate and community Climate Action Plans.

Public and stakeholder consultation has been an important component of creating the Climate Action Plan. Feedback from community members and local organizations has been included in the plan to ensure the interests of Lanark County citizens are represented. In October 2021, a stakeholder survey was sent to local organizations including those in the health, education, trades, business, energy, agriculture and food security, and natural resource sectors. The responses from this stakeholder survey were incorporated into the Climate Action Plan. In November 2022, Lanark County hosted a climate action information session where the public could learn about the Climate Action Plan and ongoing initiatives. In June 2023, the first draft of the Climate Action Plan was made available for a seven-week public comment period. A survey was created to gather feedback on the plan. The public comment period was advertised through a media release, radio interview (Lake 88.1), three public events, and social media. Local municipalities were also requested to provide feedback on the plan. 71 comments were received from the public through the survey and email and seven out of the nine local municipalities provided feedback. The results of the public comment period were incorporated into the final draft of the plan.

As we proceed with the implementation of the Climate Action Plan, engagement will be critical in meeting our emission reduction targets. Partnerships with local businesses and organizations will be key in mobilizing citizens to act against climate change. County staff will continue to strive to create meaningful opportunities for all community members to become more informed and involved with climate action. Key avenues of community engagement will be the Lanark County Climate Action Information Page, newsletter, County website, educational seminars, public events, and other media outlets.

Guiding Principles

The Climate Action Committee decided on a set of seven guiding principles to guide the development of the Lanark County Climate Action Plan. The guiding principles serve as the vision for the plan and provide a framework for current and future additions to the Climate Action Plan.

1. **Create a climate conscious culture and community**
2. **Eliminate fossil fuels**
3. **Optimize energy/water efficiency and increase renewable energy generation**
4. **Advance the use of nature-based solutions in climate change management**
5. **Sustainably manage waste towards a circular economy**
6. **Collaborate with community stakeholders**
7. **Increase funding, accessibility, and education**

Sustainable Lanark

Lanark County maintains its commitment to the 19 themes of Sustainable Lanark as identified in the Sustainable Communities Official Plan (SCOP), which include age-friendly communities, healthy communities, safety, and diversity[4]. As climate change affects different communities in diverse ways and can exacerbate existing societal issues, it is important that these core themes of Sustainable Lanark are integrated into the Climate Action Plan to reduce the disproportionate effects of climate change.

According to the Government of Canada, the health of vulnerable communities may be at an increased risk due to climate change. These communities include:

- *Seniors*
- *Youth and children*
- *Indigenous people*
- *Racialized populations*
- *People with disabilities*
- *People who are pregnant*
- *Emergency first responders*
- *People in northern and remote communities*
- *People who are socially and economically disadvantaged*
- *People who are immunocompromised and or living with a pre-existing illness*[5]

Inevitably, despite Lanark County's best efforts to reduce our greenhouse gas emissions, increases in heat and extreme weather events will still happen. To ensure the resilience of our communities, including those most vulnerable, ongoing collaboration with community groups seeking equity and justice will be a necessary component of the evolution of this plan and the creation of a climate change adaptation plan. Adaptation to climate change will be an important component to future revisions of both new and existing plans.

Local Municipal Climate Action Plans

Each local municipality is responsible for developing their own corporate climate action plan. Each local municipality can choose to adopt the Lanark County community climate action plan and its goals and targets or create their own plan specific to their community using the County's plan as a guiding framework. To achieve meaningful and measurable results, it is important that municipalities select SMART goals for their climate action plans – specific, measurable, attainable, relevant, and time-bound. Lanark County is available to assist local municipalities in the development of their community and/or corporate climate action plans. When developing climate action plans, it is recommended that each local municipality organize their plans by the same themes as those laid out in this plan. Themes help organize plans by clustering actions into understandable headings. Once completed, each local municipalities' corporate and community climate action plans can be included as chapters of this plan which outline the following information:

- *Planning for change – a discussion of each municipality's baseline greenhouse gas emissions, emissions forecasts, and emission reduction targets.*
- *Taking action – detailed goals for each theme.*
- *Implementing the plan – description of how the goals will be implemented over time.*

4 Lanark County. (2012). Sustainable Communities Official Plan. Retrieved from https://www.lanarkcounty.ca/en/doing-business/resources/documents/Planning/Microsoft-Word---SCOP---Adopted-with-approved-MMAH-Modifications-June-18-2013.pdf **5** Government of Canada. (2022). Who is most impacted by climate change. Retrieved from https://www.canada.ca/en/health-canada/services/climate-change-health/populations-risk.html

A CHANGING CLIMATE

Introduction to Climate Change

Climate change is the long-term shift in weather conditions measured by changes in temperature, precipitation, winds, and other indicators. Climate change can involve changes in average conditions, as well as changes in the frequency and severity of extreme weather events such as heat waves, flooding, droughts, and storms[6]. These shifts in climate conditions can occur naturally due to changes in the sun's activity or large volcanic eruptions. However, since the 1800s, human activities have been the main cause of climate change, primarily due to the burning of fossil fuels like coal, oil, and gas[7]. As fossil fuels are burned through activities like driving, heating homes, and powering equipment, greenhouse gases are released into the atmosphere. Greenhouse gases are also released through other human practices such as waste management (e.g., solid waste sent to landfills), land-use decisions (e.g., development and forestry), and agricultural activities (e.g., livestock and manure management).

Greenhouse gases get their name because when they are released in the atmosphere, they act as an insulator, trapping the sun's heat and keeping the Earth's surface warm[8]. This process is referred to as the "greenhouse effect" because greenhouse gases make the earth warmer, just as a greenhouse is warmer than its surroundings (Figure 3). As humans increase the concentration of greenhouse gases, particularly carbon dioxide (CO2), more heat is trapped in the atmosphere and the Earth's temperature rises. Since humans are emitting greenhouse gases at a rate faster than ever before, climate change threatens to warm the planet to levels that have never been experienced in the history of human civilization, making it extremely challenging for human societies and the natural world to adapt[9].

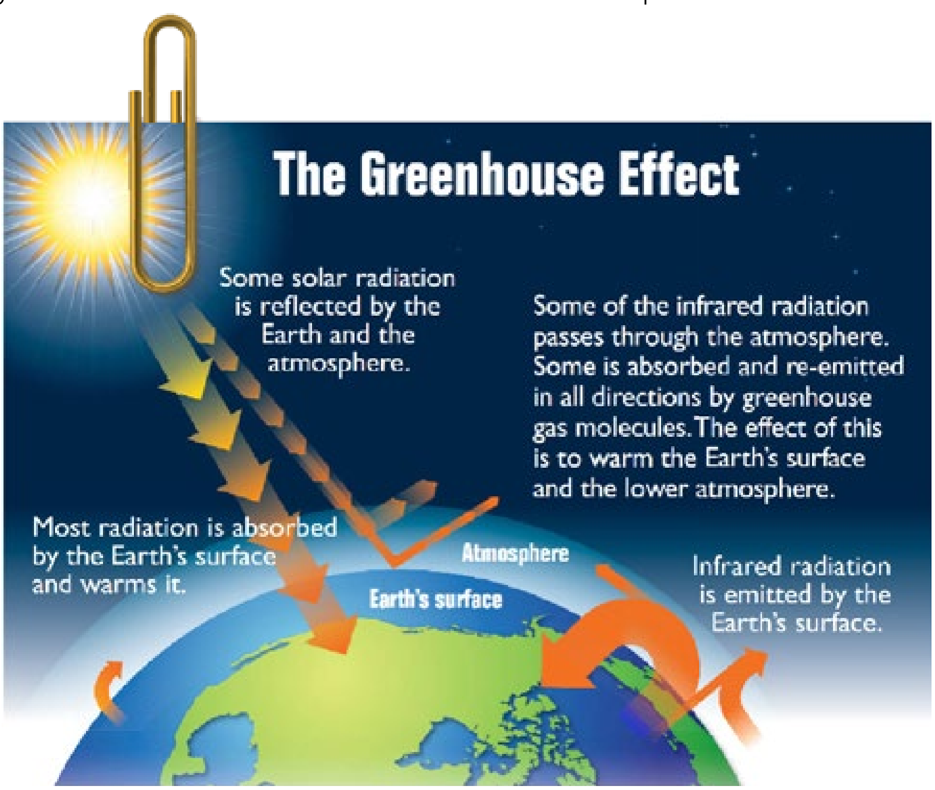


Figure 3. The greenhouse effect[10].

6 Government of Canada. (2019). Causes of climate change. Retrieved from https://www.canada.ca/en/environment-climate-change/services/climate-change/causes.html **7** United Nations. (n.d.). What Is Climate Change? Retrieved from https://www.un.org/en/climatechange/what-is-climate-change#:~:text=Climate%20change%20refers%20to%20long,activity%20or%20large%20volcanic%20eruptions **8** Ibid 7 **9** Ibid 7 **10** Energy Education. (n.d.). Greenhouse effect. Retrieved from https://energyeducation.ca/encyclopedia/Greenhouse_effect

What is the difference between weather and climate?

Weather refers to the day-to-day state of the atmosphere relative to a place and time. Weather can be described by the heat, dryness, sunshine, cloud cover, wind, and rain conditions of a place at a certain time. Weather is more variable than climate and is usually assessed for a localized area over a short period of time (i.e., minutes, hours, days, weeks). Climate, however, refers to the long-term weather conditions in a place or region over a long period of time. An assessment of climate is usually 30 years or more. To differentiate between the two concepts, climate can be described as "what you expect", whereas weather is "what you get". As climate change progresses, weather patterns change which results in a shift in what you can expect in the region[11].

What is the difference between global warming and climate change?

The terms "global warming" and "climate change" are often used interchangeably, but they are not the same. Global warming is a term that describes the long-term increase in global average surface temperature. Global warming is only one aspect of climate change. Climate change more broadly describes the long-term changes that are happening to our planet such as rising sea levels, increased frequency and severity of extreme weather events, and accelerated ice melt[12].

Why do some places experience record-breaking cold and snowfall if the climate is warming?

A warming climate results in the disruption of the Earth's natural processes. Extreme cold in areas is due to the decreasing stability of the polar vortex. Polar vortices are low-pressure systems located in the north and south poles. The low pressure of this vortex typically keeps cold air contained in the arctic regions. As the arctic warms, the pressure in the vortex weakens resulting in the expansion of the polar vortex into more temperate areas[13]. Additionally, a warmer climate results in more water vapor in the air which can lead to greater than average snowfall in some areas[14].

Why be concerned about a degree or two change in the average global temperature?

Even though one or two degrees seems insignificant, this increase in average global temperature can create widespread changes with negative impacts on natural and human systems in Lanark County and around the world. For example, some oceanic island countries are at risk of losing their entire nations due to rising sea levels[15]. In Canada, some of the top climate change risks include changes to agriculture and food systems, coastal communities, ecosystems, fisheries, forestry, geopolitical dynamics, governance and capacity, human health and wellness, Indigenous ways of life, northern communities, physical infrastructure, and water[16].

11 NASA. (2017). Weather or climate change? Retrieved from https://climate.nasa.gov/explore/ask-nasa-climate/2632/weather-or-climate-change/ **12** NASA. (2022). What's the difference between climate change and global warming? Retrieved from https://climate.nasa.gov/faq/12/whats-the-difference-between-climate-change-and-global-warming/ **13** Science. (2021). Linking Arctic variability and change with extreme winter weather in the United States. Retrieved from https://www.science.org/doi/10.1126/science.abi9167 **14** EPA. (2022). Frequently Asked Questions About Climate Change. Retrieved from https://www.epa.gov/climatechange-science/frequently-asked-questions-about-climate-change#weather-climate **15** Scientific Reports. (2019). Vulnerability to climate change of islands worldwide and its impact on the tree of life. Retrieved from https://www.nature.com/articles/s41598-019-51107-x **16** Council of Canadian Academies. (2019). Canada's Top Climate Change Risks. Retrieved from https://www.cca-reports.ca/reports/prioritizing-climate-change-risks/#:~:text=Canada%E2%80%99s%20Top%20Climate%20Change%20Risks%20identifies%2012%20major,life%2C%20northern%20communities%2C%20physical%20infrastructure%2C%20and%20water.%20

Climate Change in Lanark County

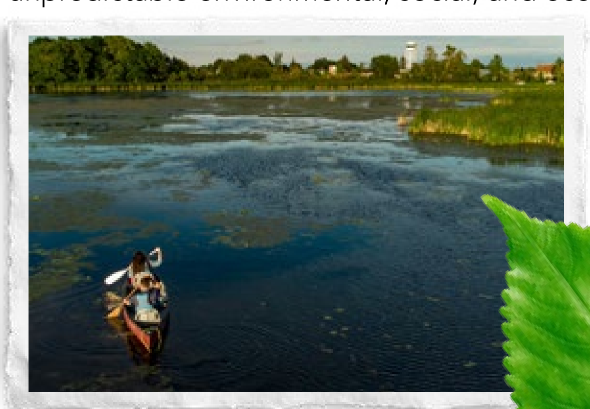
Due to Canada's high northern latitude and large land mass, it is warming twice as fast as the global average and at an even greater rate in the Canadian Arctic[17]. While both human activities and natural climatic variations are factors in the observed warming in Canada, it is likely that more than half of the observed warming is due to human activities. As the climate continues to shift across Canada, the impacts will be felt locally in Lanark County.

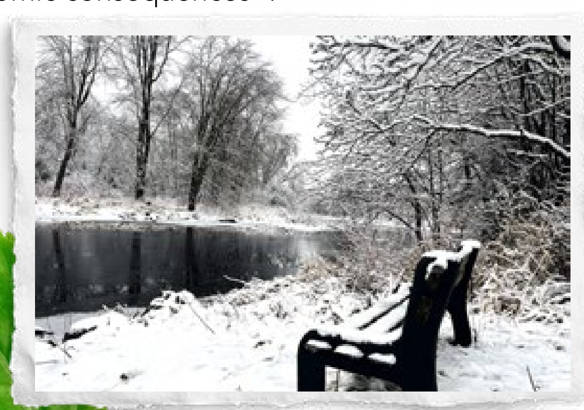
Heat waves, floods, droughts, and storms have always been present in Ontario and Lanark County. However, the frequency and intensity of these extreme weather events are shifting. These changes threaten our local health, safety, environment, and economy. Between 1948 and 2012, the average annual temperature in Ontario increased by 1.5°C[18]. By 2050, it is estimated that the average annual temperature in Ontario could increase by another 2.5°C to 3.7°C[19].

By 2050, if no action is taken to mitigate climate change, Lanark County could experience[20]:

- *A 2.1°C increase in average annual temperature*
- *A 14% increase in length of the frost-free season*
- *Roughly 5 heat waves per year (at least 3 days or longer exceeding 30°C)*
- *A 2 day increase in the length of heat waves, resulting in heat waves lasting around 6 days*
- *15 extremely hot days (+32°C) per year*
- *An 8% increase in maximum 3-day precipitation*
- *A 21 day decrease in the number of frost days, meaning we will only experience 134 days per year which go below 0°C*
- *A 15 day decrease in the number of icing days, meaning we will only experience 58 days per year where the temperature will remain below 0°C*
- *A 31 day increase in the number of days above 30°C, bringing the total to 95 days per year*

These climate projections come from the Climate Atlas of Canada, which uses simulations of Earth's future climate conditions based on assumptions of the concentrations of greenhouse gases and other atmospheric constituents. These projections capture the relationships between human actions, emissions, and climate change to help us plan and adapt to future climate conditions. While these changes may seem small, they will have widespread and unpredictable environmental, social, and economic consequences[21].





17 Government of Canada. (2019). Canada's Changing Climate Report. Retrieved from https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf **18** Government of Ontario. (2023). Ontario Provincial Climate Change Impact Assessment. Retrieved from Ontario Provincial Climate Change Impact Assessment Technical Report - January 2023 **19** Government of Ontario. (2021). Climate change. Retrieved from https://www.ontario.ca/page/climate-change **20** Climate Atlas of Canada. (n.d.). https://climateatlas.ca/ **21** Environment and Climate Change Canada. (2019). Canada in a Changing Climate Report. Retrieved from https://changingclimate.ca/CCCR2019

Impacts of Climate Change

Without intervention, climate change will impact all aspects of life in Lanark County. The following list, though not exhaustive, summarizes the key risks and impacts that Lanark County may experience as a result of climate change:

Heat and drought, impacting local water supply and agricultural practices

Illness and disease due to increased heat stress and poor air quality

More ice storms, threatening safety and damaging infrastructure

Increase in zoonotic and vector borne diseases

Damage to infrastructure, risking critical water, sanitary, and power systems

Disruptions to the economy as infrastructure and assets are threatened

Loss of native biodiversity, increasing the introduction of invasive species, pests, and disease

Soil erosion and nutrient loss impacting local agricultural systems Increased risk of flooding and fire

Mental health challenges caused by climate change stressors

Increased risk of flooding and fire

PLANNING

FOR CORPORATE CHANGE

Corporate Emissions Inventory

To achieve Milestone 1 of the Partners for Climate Protection Program, Lanark County completed a corporate greenhouse gas emissions inventory for our base year (2019). The corporate inventory was completed following the PCP protocol, which outlines a set of clear accounting and reporting guidelines for developing greenhouse gas inventories within the context of the PCP program. The sectors that the corporate greenhouse gas emissions inventory tracks include corporate buildings, vehicles, water and sewage, and waste. The inventory identifies which corporate sectors use the most energy and have the greatest emissions and, thus, can be used to focus resources and emission reduction strategies accordingly. The greenhouse gas inventory also provides an important benchmark from which to measure the success of the Corporate Climate Action Plan over time.

In 2019, 2,462 tonnes of CO2e were emitted from Lanark County corporate operations. Corporate greenhouse gas emissions were estimated using electricity and gas bills, fuel reports, and waste collection tonnage reports. The largest source of corporate emissions are County-owned buildings, which include the Administration and Public Works offices, Lanark Lodge long-term care facility, four public works garages, and the Lanark County Housing Corporation (LCHC) portfolio. Together, these buildings account for 63% of total emissions (Figure 4). Corporate vehicles are the second largest source of corporate emissions, accounting for 27% of emissions.

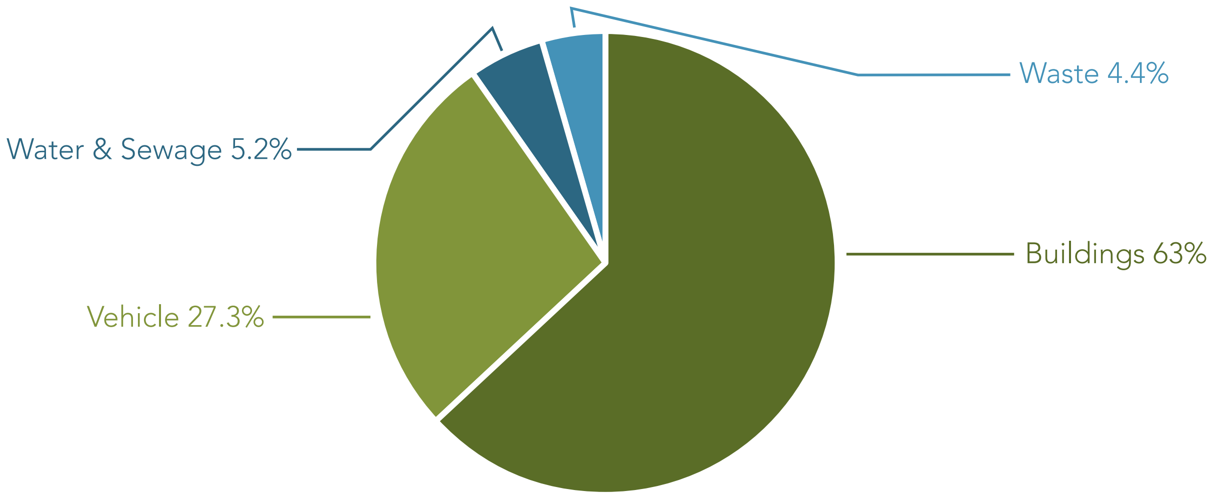


Figure 4: Lanark County's corporate greenhouse gas emissions by sector from the baseline year 2019.

Natural gas is the energy source responsible for the largest proportion (58%) of greenhouse gas emissions in Lanark County's corporate operations (Figure 5). The remaining greenhouse gas emissions are sourced from diesel (19%), electricity (13%), gasoline (9%), and propane (<1%).

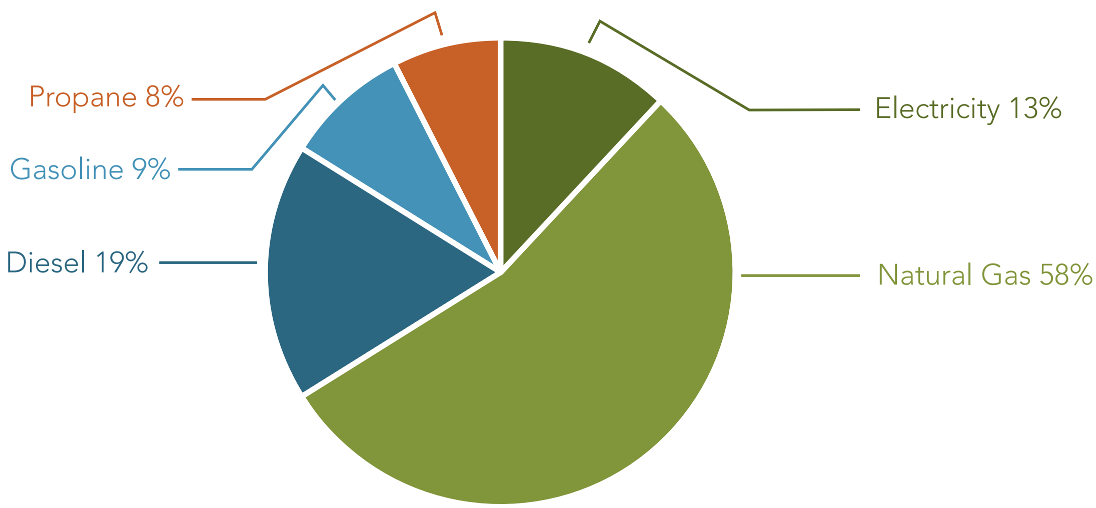


Figure 5. Lanark County's corporate greenhouse gas emissions by energy source.

Corporate Business as Usual Forecast

Business as usual (BAU) scenarios are created to help understand what would happen to greenhouse gas emissions if no actions were taken. These scenarios are valuable in setting targets as any target must offset the forecasted growth in emissions. Without action, it is projected that the corporate greenhouse gas emissions will rise by 76% by 2050, for a total of 4333 tonnes CO_2e (Figure 6). The business as usual forecast assumes that corporate emissions will grow linearly with population growth. Since not all corporate sectors are expected to expand significantly by 2050 (e.g., administration and public works buildings), the current assumption of a one-to-one relationship between corporate emissions and population growth is likely an overestimation. The corporate business as usual forecast can be updated to reflect future proposed plans for Lanark County corporate operations.

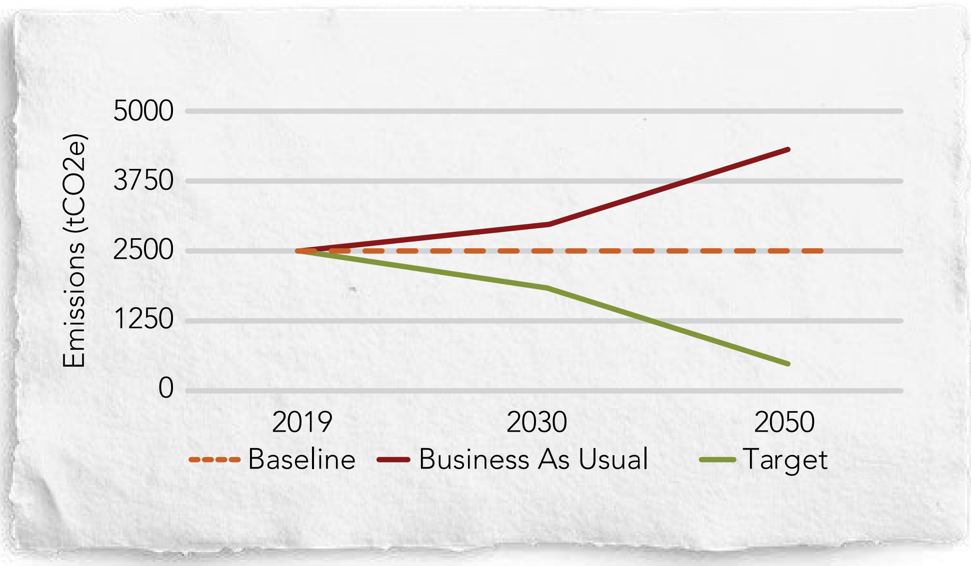


Figure 6. Lanark County corporate greenhouse gas emissions under different scenarios (baseline, business as usual, targets).

Corporate Emissions Reduction Targets

Lanark County's 2019 greenhouse gas emissions inventory will serve as the baseline for corporate emissions reduction targets. Recognizing that different mitigation actions take varying amounts of time to develop, gain traction, and result in a measurable change in greenhouse gas emissions, Lanark County will adopt mid- and long-term emissions reduction targets. Lanark County has set the following corporate emissions reduction targets:

25% below 2019 levels by 2030
80% below 2019 levels by 2050

The mid- and long-term targets will be assessed regularly and have the potential to be increased upon progress and technological advancements.

TAKING ACTION - CORPORATE CLIMATE ACTION PLAN

Overview and Structure

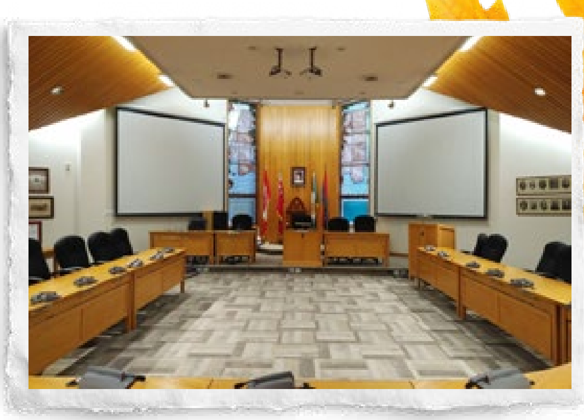
The Corporate Climate Action Plan outlines how Lanark County will reduce greenhouse gas emissions in its corporate operations and services including County-owned buildings, fleet, streetlights, water and sewage treatment, and solid waste. While these emissions make up a small proportion of all of Lanark County's emissions, creating a corporate Climate Action Plan presents an opportunity for the County to demonstrate leadership in climate action.

During the Corporate Climate Action Plan development process, 29 goals were identified to reduce Lanark County's corporate greenhouse gas emissions and build resilience to the impacts of climate change. Each corporate goal has information on potential benefits, cost and funding source, start time, approximate timeframe for completion, department or person responsible, key performance indicators, and estimated greenhouse gas reductions. The goals may evolve over time as the plan progresses.

The Corporate Climate Action Plan is organized by the seven following themes which seek to address the greatest sources of greenhouse gas emissions within the corporation of Lanark County:

- **Education**
- **Buildings and energy**
- **Lanark County Housing Corporation**
- **Transportation and equipment**
- **Natural Heritage and resources**
- **Waste diversion and management**
- **Planning**

Refer to Appendix B for descriptions of costs and timeframe for completion.



Theme 1 – Education

Education is the first theme of the Corporate Climate Action Plan. Reducing corporate emissions will be a collective effort of all Lanark County staff and decision makers. By building their knowledge, attitudes, and behaviours towards climate change, Lanark County will be able to respond more promptly to reach our emission reduction targets.

GOAL 1.1 - Modify all Council reports to include a section for the climate impact that uses the climate tool	
Potential Benefits	Reduce fossil fuels, encourage a climate conscious culture
Cost and Funding Source	None
Person or Department Responsible	Chief Administrative Officer / Clerk
Start Time	In progress; 2023
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of projects/decisions assessed
Expected GHG Reduction	Indirect; Medium

GOAL 1.2 - Raise staff awareness of corporate climate initiatives through mini campaigns and training programs	
Potential Benefits	Encourage a climate conscious culture
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate Environmental Department
Start Time	2023
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of staff trained, # of campaigns
Expected GHG Reduction	Indirect; Low

GOAL 1.3 - Launch an Off Nightly/Mini campaign to encourage staff to turn off computers, printers, and lights over night or when not in use	
Potential Benefits	Reduce energy costs, encourage a climate conscious culture
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate Environmental Department
Start Time	2024
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Energy consumption data
Expected GHG Reduction	Indirect; Low

Theme 2 – Buildings and Energy

Corporate buildings are responsible for the largest source of corporate greenhouse gas emissions (63%). To reach the corporate emissions reduction targets, it will be necessary to carry out energy retrofits on all buildings, reducing energy demand and facilitating the rapid decrease of fossil fuel usage. Through building envelope and system improvements, built environment energy demands could be reduced significantly to the point where renewable energy generation could feasibly bring corporate buildings to net zero ready or net zero energy performance.

GOAL 2.1 - Plan for the rebuild or retrofit of all County buildings to be net-zero	
Potential Benefits	Reduce fossil fuel, reduce energy costs, reach net-zero
Cost and Funding Source	High; County Budget, Green Municipal Fund Capital Funding
Person or Department Responsible	Chief Administrative Officer
Start Time	To be determined
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Pre- and post-energy audit data, completed feasibility study
Expected GHG Reduction	Direct; High

GOAL 2.2 - Conduct a building automation system maintenance/commissioning	
Potential Benefits	Reduce fossil fuels, reduce energy costs
Cost and Funding Source	Low; County Budget
Person or Department Responsible	Facilities Coordinator
Start Time	In progress
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Maintenance reports
Expected GHG Reduction	Direct; Medium

GOAL 2.3 - Install solar systems on municipal buildings where possible	
Potential Benefits	Increase renewable energy generation, reduce fossil fuels
Cost and Funding Source	High; County Budget
Person or Department Responsible	Facilities Coordinator
Start Time	In progress; 2018
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of panels installed
Expected GHG Reduction	Direct; Medium

GOAL 2.4 - Install motion sensors for indoor lighting and automatic timers on all equipment that can be turned off at night	
Potential Benefits	Reduce energy costs
Cost and Funding Source	Low; County Budget
Person or Department Responsible	Facilities Coordinator
Start Time	In progress; 2009
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Energy consumption data, # of timers/ sensors installed
Expected GHG Reduction	Direct; Low

GOAL 2.5 - Optimize heating and cooling efficiency in all County buildings to reduce energy consumption	
Potential Benefits	Reduce fossil fuels, reduce energy costs
Cost and Funding Source	Low; County Budget
Person or Department Responsible	Facilities Coordinator
Start Time	To be determined upon replacement schedules
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Energy consumption data
Expected GHG Reduction	Direct; Medium

QUICK FACT:
A deep retrofit is a complete overhaul of a building that aims to reduce and improve heat loss and energy consumption. These retrofits involve updating components such as windows, heating systems, energy sources, and insulation in walls and roofs.

Theme 3 – Lanark County Housing Corporation

The Lanark County Housing Corporation (LCHC) is captured within the corporate buildings sector in the greenhouse gas emissions inventory and accounts for 47% of corporate emissions alone. The LCHC provides over 500 dwellings for low-income tenants in 29 developments across the County. The building portfolio consists of a combination of low-rise complexes, single-family homes, and attached and semi-detached homes. The affordable housing sector faces unique challenges in undertaking energy efficiency projects including, but not limited to, an aging housing stock and limited staff and resource capacity. The Climate and Environmental Department will continue to work with the LCHC to help identify opportunities and secure funding to reduce the climate impact of the LCHC and create opportunities for tenants to participate in climate change mitigation and adaptation.

GOAL 3.1 - Encourage energy efficient practices by increasing tenant education (e.g., providing energy efficient tips through mailing list, posters in common spaces, reporting improvements to tenants, etc.)	
Potential Benefits	Improve efficiency, reduce energy costs
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate Environmental Department / Social Services Department
Start Time	2024
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of tenants engaged, # of resources created
Expected GHG Reduction	Indirect; Low
GOAL 3.2 - Complete energy audits to identify the most effective energy-saving opportunities and prioritize projects when possible	
Potential Benefits	Identify opportunities to improve efficiency and reduce energy costs and greenhouse gas emissions
Cost and Funding Source	High; Canada Mortgage and Housing Corporation (Canada Greener Affordable Housing), Deep Retrofit Accelerator Initiative, Green Municipal Fund (Sustainable Affordable Housing), Social Services Budget, Climate Change Budget
Person or Department Responsible	Social Services Department
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of buildings audited, pre-energy retrofit audit data
Expected GHG Reduction	Indirect; High

GOAL 3.3 - Improve building envelope performance to reduce demand on heating and cooling systems, reduce energy loss, and increase tenant comfort (e.g., increase existing insulation, replace windows and doors with high efficiency models as needed)	
Potential Benefits	Reduce fossil fuels, reduce energy costs, increase tenant comfort
Cost and Funding Source	Medium; Green Municipal Fund (Sustainable Affordable Housing), Social Services Budget
Person or Department Responsible	Social Services Department
Start Time	In progress; 2016
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of units improved, R-values, consumption data
Expected GHG Reduction	Direct; High
GOAL 3.4 - Improve domestic hot and cold water system efficiency to reduce energy costs and losses (e.g., upgrading to high efficiency systems when system is at end of life, installing pipe insulation and tank insulator blankets etc.)	
Potential Benefits	Reduce fossil fuels, improve efficiency, reduce energy costs
Cost and Funding Source	Medium; Social Services Budget
Person or Department Responsible	Social Services Department
Start Time	In progress; 2016
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of units improved, consumption data
Expected GHG Reduction	Direct; Medium
GOAL 3.5 – Replace appliances beyond their service life with Energy Star models	
Potential Benefits	Reduce fossil fuels, improve efficiency, reduce energy costs
Cost and Funding Source	Medium; Social Services Budget
Person or Department Responsible	Social Services Department
Start Time	In progress; 2016
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of appliances replaced
Expected GHG Reduction	Direct; Medium

GOAL 3.6 - Construct new buildings to be energy efficient	
Potential Benefits	Reduce fossil fuels, reduce energy costs
Cost and Funding Source	High; Green Municipal Fund (Sustainable Affordable Housing), Social Services Budget
Person or Department Responsible	Social Services Department
Start Time	To be determined
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Building certifications
Expected GHG Reduction	Direct; High

GOAL 3.7 - Consider electric heat pumps in the replacement of electrical baseboards and gas furnaces/boilers at end of life	
Potential Benefits	Reduce fossil fuels, reduce energy costs, increase tenant comfort
Cost and Funding Source	High; Green Municipal Fund (Sustainable Affordable Housing), Social Services Budget
Person or Department Responsible	Social Services Department
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of heat pumps installed
Expected GHG Reduction	Direct; High

GOAL 3.8 - Explore the conversion of areas to pollinator habitat or food production on managed properties	
Potential Benefits	Increase pollinator habitat, reduce emissions from mowing and maintenance, increase food security, increase resident engagement
Cost and Funding Source	Low; Climate Change budget
Person or Department Responsible	Climate Environmental Department / Social Services Department
Start Time	2024
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	Area of land converted
Expected GHG Reduction	Direct; Low

Theme 4 – Transportation and Equipment

Corporate fleet, which includes Lanark County owned vehicles and equipment, is the second largest emitting corporate sector, responsible for 27.3% of corporate greenhouse gas emissions. Transitioning to electric vehicles and equipment will be essential in reaching our corporate emission reduction targets. Where electric options are not available, the County will explore the use of low-carbon fuel and hybrid options.

GOAL 4.1 - Upgrade 16 gas and 3 diesel fleet vehicles to electric vehicles by 2030 when electric vehicles are available/vehicles reach end of life	
Potential Benefits	Reduce fossil fuels, increase EV uptake
Cost and Funding Source	High; Public Works Budget, Federal Incentives for Zero-Emission Vehicles Program, Green Municipal Fund Capital Funding
Person or Department Responsible	Director of Public Works
Start Time	In progress; 2023
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of vehicles replaced
Expected GHG Reduction	Direct; High
GOAL 4.2 - Install electric vehicle charging stations at the County buildings for County fleet charging and for staff, councillors or the public to use	
Potential Benefits	Reduce fossil fuels, encourage a climate conscious culture
Cost and Funding Source	Medium; Public Works / Climate Change Budget, Natural Resources Canada Zero-Emission Vehicle Infrastructure, Green Municipal Fund Capital Funding
Person or Department Responsible	Facilities Coordinator
Start Time	In progress; 2022
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	# of chargers, usage data
Expected GHG Reduction	Indirect; Low
GOAL 4.3 - The procurement of new or replacement equipment or power tools be electric, unless an electric option is not available	
Potential Benefits	Reduce fossil fuels
Cost and Funding Source	Medium; Public Works Budget
Start Time	2024
Person or Department Responsible	Director of Public Works
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	# of equipment procured, usage data
Expected GHG Reduction	Direct; Medium

Theme 5 – Natural Heritage and Resources

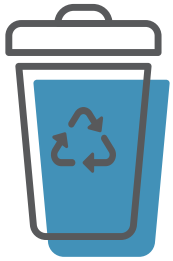
Protecting and increasing the coverage of natural features helps to mitigate climate change and promote biodiversity. Since 2018, Lanark County has taken steps to help support pollinators, wildlife, and increase tree coverage. Continuing this work on available County-owned properties will contribute to reaching our corporate climate targets.

GOAL 5.1 - Increase the tree canopy on County properties (e.g., LCHC properties, County offices etc.)	
Potential Benefits	Sequester carbon, protect natural resources, improve biodiversity, improve climate change mitigation, improve climate change adaptation, preserve and/or improve ecosystem services
Cost and Funding Source	Low; Climate Change Budget, Public Works Budget
Person or Department Responsible	Climate and Environmental Department
Start Time	In progress
Approximate Timeframe for Completion	On-going
Key Performance Indicators	# of trees planted
Expected GHG Reduction	Direct; Low (carbon offsets)

GOAL 5.2 - Increase carbon sequestration and pollinator habitat on County properties and road allowances	
Potential Benefits	Sequester carbon, protect natural resources, improve biodiversity, improve climate change mitigation, preserve and/or improve ecosystem services
Cost and Funding Source	Low; Climate Change Budget, Public Works Budget
Person or Department Responsible	Climate and Environmental Department
Start Time	In progress; 2016
Approximate Timeframe for Completion	On-going
Key Performance Indicators	Acres of restored land
Expected GHG Reduction	Direct; Low (carbon offsets)

GOAL 5.3 - Explore approaches that incorporate natural systems and green infrastructure into site improvements, greenspaces, and stormwater management (e.g., rain gardens, trees etc.)	
Potential Benefits	Sequester carbon, protect natural resources, improve biodiversity, improve climate change mitigation, preserve and/or improve ecosystem services
Cost and Funding Source	Low; Climate Change Budget, Public Works Budget
Person or Department Responsible	Climate and Environmental Department
Start Time	2024
Approximate Timeframe for Completion	On-going
Key Performance Indicators	# of projects
Expected GHG Reduction	Direct; Low

DID YOU KNOW? Not only do native plants benefit pollinators, they also help with climate change. Native plants are champions for carbon sequestration. Their deep root systems allow them to capture a significantly higher amount of carbon when compared to turf grass, non-native species, and annual plants. To find a list of native plants to incorporate in your yard, visit: Pollinator Conservation Resources: Great Lakes Region | Xerces Society



Theme 6 – Waste Diversion and Management

Although waste accounts for only 4% of corporate emissions, Lanark County will continue to improve our waste management practices to reduce the amount of waste that enters the landfill.

GOAL 6.1 - Join the Blue Communities Project and phase out the sale of bottled water in municipal facilities and at municipal events	
Potential Benefits	Reduce plastic waste, encourage a climate conscious culture
Cost and Funding Source	Low; CC Budget
Person or Department Responsible	Climate Environmental Department and Local Municipalities
Start Time	2024
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Reduction/elimination of bottled water
Expected GHG Reduction	Indirect; Low

GOAL 6.2 - Install water refill stations in all municipal buildings to replace water coolers	
Potential Benefits	Reduce fossil fuels from water transportation, reduce plastic waste
Cost and Funding Source	Low; County Budget
Person or Department Responsible	Facilities Coordinator
Start Time	In progress; 2023
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	# of bottles saved (water refill station data)
Expected GHG Reduction	Indirect; Low

GOAL 6.3 - Launch an enhanced recycling program for plastic, glass, metal and food waste (e.g., Terracycle 25% of waste)	
Potential Benefits	Increase recycling, divert waste from landfills
Cost and Funding Source	Low; County Budget
Person or Department Responsible	Climate Environmental Department
Start Time	2024
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	# of kgs recycled, programs joined
Expected GHG Reduction	Indirect; Low

GOAL 6.4 - Purchase 100% recycled paper and enact policies and procedures to reduce the overall use of paper	
Potential Benefits	Reduce waste, encourages a climate conscious culture
Cost and Funding Source	Low; County Budget
Person or Department Responsible	All departments
Start Time	To be determined
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	Purchasing data
Expected GHG Reduction	Indirect; Low

QUICK FACT:

What is a Circular Economy?

A Circular Economy is an economy in which participants strive to:

- minimize the use of raw materials;
- maximize the useful life of materials and other resources through resource recovery; and
- minimize waste generated at the end-of-life of products and packaging.

To learn more about how the federal government is supporting circular strategies, visit:

Circular Economy- Government of Canada

Theme 7 - Planning

Climate change adaptation means planning for and acting on the anticipating impacts of climate change. By taking action to plan for and adapt to the changing climate, Lanark County can build a stronger and more resilient community. To build momentum, it is imperative that policies, plans, and processes at the county level include climate change considerations. Updating existing plans to reflect the risks associated with climate change and the importance of natural infrastructure in adaptation and mitigation will help inform decision making.

GOAL 7.1 - Revise the Asset Management Plan to include natural assets (e.g., watersheds, wetlands, forests, lakes etc.)	
Potential Benefits	Better preparedness for the future
Cost and Funding Source	Medium; County Budget, Climate Change Budget, FCM (Municipal Asset Management Program)
Person or Department Responsible	Climate and Environmental Department, Planning Departments of the County and local municipalities, CAO, RVCA, MVCA community stakeholders
Start Time	2025
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Completion of Asset Management Plan
Expected GHG Reduction	Indirect; Low
GOAL 7.2 - Update Emergency Plan to include protocols for major natural disasters and weather events (e.g., evacuation routes, shelter locations, etc.)	
Potential Benefits	Better preparedness for the future
Cost and Funding Source	Medium; County Budget, Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, Planning Departments of the County and local municipalities, CAO, RVCA, MVCA community stakeholders
Start Time	2025
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Completion of Emergency Plan
Expected GHG Reduction	None

GOAL 7.3 - Create an inclusive adaptation plan that captures Lanark County's risks and vulnerabilities to climate change (e.g., health, food security/sovereignty, environmental hazards, improved land-use, safety measures)	
Potential Benefits	Better preparedness for the future
Cost and Funding Source	Medium; County Budget, Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, Planning Departments of the County and local municipalities, CAO, RVCA, MVCA community stakeholders
Start Time	2024
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Completion of Adaptation Plan
Expected GHG Reduction	None

PLANNING
FOR COMMUNITY CHANGE

Community Emissions Inventory

To achieve Milestone 1 of the Partners for Climate Protection Program, Lanark County completed a community greenhouse gas emissions inventory for our base year (2019). The community inventory was completed following the PCP protocol, which outlines a set of clear accounting and reporting guidelines for developing greenhouse gas inventories within the context of the PCP program. The sectors that the community emissions inventory tracks include stationary energy, transportation, waste, agriculture, and forestry. The greenhouse gas inventory identifies which community sectors use the most energy and have the greatest emissions and, thus, can be used to focus resources and emission reduction strategies accordingly. The community greenhouse gas inventory also provides an important basis from which to measure the success of the Community Climate Action Plan over time.

In 2019, 696,972 tonnes of CO2e were emitted from the Lanark County community as a whole. Community greenhouse gas emissions were estimated using total electricity and gas data from Hydro One, Enbridge, and Ottawa River Power Corp.; vehicle registration and vehicle kilometres travelled data from the Clean Air Partnership; waste data from each municipality; and forest carbon sequestration and livestock emission estimates from Greenscale Inc. On-road transportation is the largest source of greenhouse gas emissions in the community, accounting for 63.6% of total emissions (Figure 7). The second largest source of community emissions is residential buildings, which account for 16.6% of community emissions.

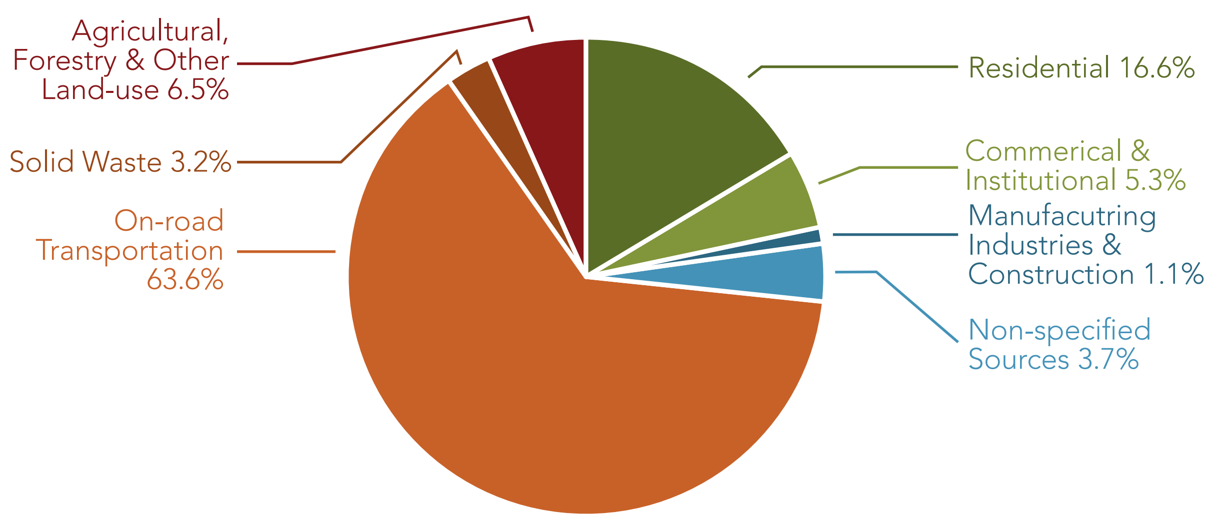


Figure 7: Lanark County's community greenhouse gas emissions by sector from the baseline year 2019.

On-road transportation fuel is the energy source responsible for the largest proportion (70%) of greenhouse gas emissions from Lanark County as a whole (Figure 8). The remaining greenhouse gas emissions are sourced from natural gas (20%), electricity (3%), fuel oil (4%), and propane (3%).

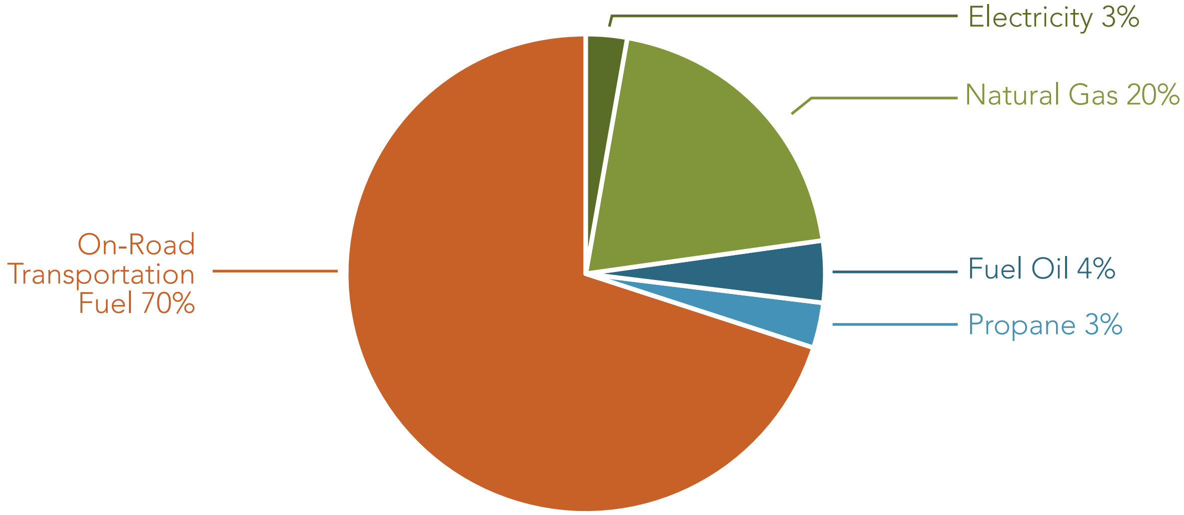


Figure 8. Lanark County's community greenhouse gas emissions by energy source.

Community Business as Usual Forecast

Business as usual (BAU) scenarios are created to help understand what would happen to greenhouse gas emissions if no actions were taken (Figure 9). Without action, by 2050, it is projected that community emissions will increase to 747,821 tonnes CO2e. These scenarios are valuable in setting targets as any target must offset the forecasted growth in emissions.

The BAU forecast is based on the best available data showing an estimated 1.84% annual County-wide population growth rate for 2019. Applying this population growth rate to all greenhouse gas inventory sectors results in a 20% increase in total forecasted emissions for the mid-term (2019 to 2030) and a 76% increase in the long-term (2019 to 2050). Assuming this simplified one-to-one relationship between population growth and emissions likely overestimates future emissions. Thus, the Lanark County community BAU forecast broke down projected emissions by sector under various assumptions outlined in Table 3 of Appendix A. The BAU annual growth rate in the transportation, residential, and stationary energy sectors was initially dampened to 0.92%, equal to half the expected population growth rate due to the assumption that there is not a linear relationship between population growth and emissions in these sectors. For example, new homes may house 2 to 5 people, while there may only be 1 or two vehicles per household. Similarly, 2 people in the same house do not necessarily use twice as much energy as a one-person household. With an assumed decrease in emissions of 0.75% per year in the transportation, residential, and stationary energy sectors due to projected fuel efficiency and building code improvements, this translates to a net BAU growth of 0.17% per year in those sectors. The BAU forecast assumes a 1.84% annual GHG growth rate in the community solid waste/wastewater sector and a 0% annual GHG growth rate in the agriculture/forests sector.

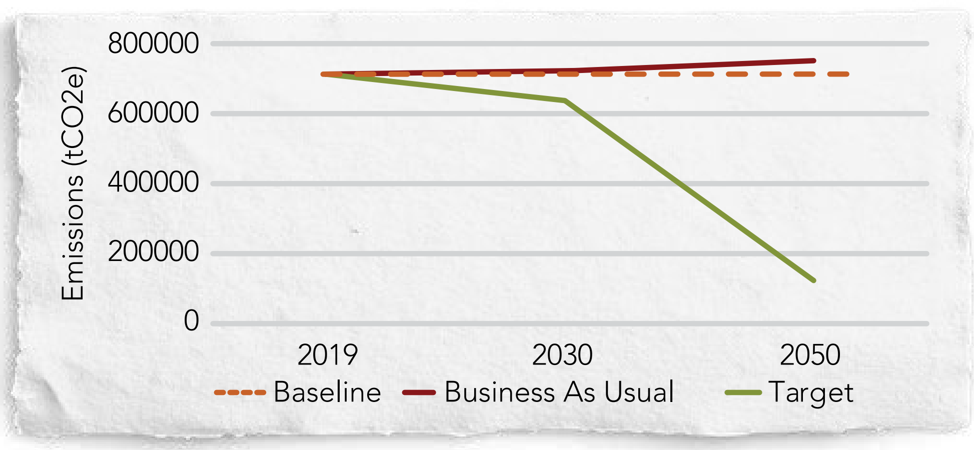


Figure 9. Community greenhouse gas emissions under different scenarios (baseline, business as usual, emission reduction targets).

Community Emissions Reduction Targets

Lanark County's 2019 greenhouse gas emissions inventory will serve as the baseline for community emission reduction targets. Recognizing that different mitigation actions take varying levels of time to develop, gain traction, and result in a measurable change in greenhouse gas emissions, Lanark County will adopt mid- and long-term emissions reduction targets. Lanark County has set the following community emissions reduction targets:

10% below 2019 levels by 2030
80% below 2019 levels by 2050

The mid- and long-term targets will be assessed regularly and have the potential to be increased upon progress and technological advancements.

TAKING ACTION - COMMUNITY CLIMATE ACTION PLAN

Overview and Structure

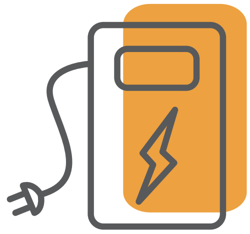
The Community Climate Action Plan outlines how Lanark County will reduce greenhouse gas emissions in the community at large. Community sources of greenhouse gas emissions include stationary energy (residential, commercial, institutional, and industrial); transportation; and waste.

During the Community Climate Action Plan development process, 21 goals were identified to reduce Lanark County's greenhouse gas emissions and build resilience to the impacts of climate change. Each community goal consists of a recommended approach, which outlines specific actions to help implement and achieve the goal. The recommended approaches do not outline each action needed to achieve the goal, but rather act as a guide for progressing forward with each goal. Each community goal also has information on potential benefits, cost and funding source, start time, approximate timeframe for completion, department or person responsible, key performance indicators, and estimated greenhouse gas reductions. Goals and recommended approaches may evolve over time as the plan and technology progress.

The Community Climate Action Plan is organized by five major themes:

- **Transportation**
- **Buildings and Energy**
- **Natural Heritage and Resources**
- **Waste Diversion and Management**
- **Planning**

Refer to Appendix B for descriptions of costs and timeframe for completion.



Theme 1 – Transportation

On-road transportation is the largest emitting community sector, responsible for 63.6% of community greenhouse gas emissions. Due to the geographic size and dispersed nature of Lanark County, community members, particularly commuters and those living in rural areas, are highly dependent on personal vehicles for transportation. Transitioning to electric transportation and finding innovative transit solutions suitable for rural communities will be integral to reducing greenhouse gas emissions within the transportation sector.

GOAL 1.1 - Increase electric vehicle uptake and local charging infrastructure for public access	
Recommended Approach	Contract companies to install chargers on public streets, and municipal buildings or property to increase public access to charging
	Launch an educational campaign for electric vehicles that encourages vehicle owners to take advantage of electric vehicle subsidy programs
Potential Benefits	Reduce fossil fuels, increase electric vehicle uptake
Cost and Funding Source	High; Natural Resources Canada Zero Emission Vehicle Infrastructure Program, Lanark County EV Fund
Person or Department Responsible	Climate and Environmental Department, local municipalities
Start Time	2024
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	# of stations installed, engagement data, charging station usage data, # of municipalities utilizing funding
Expected GHG Reduction	Direct; Medium

GOAL 1.2 - Electrify municipal and community fleet vehicles as part of their replacement cycle	
Recommended Approach	Partner with Lanark Transportation Association to electrify fleet
	Encourage local municipalities to take advantage of electric vehicle subsidy programs
Potential Benefits	Reduce fossil fuels, increase electric vehicle uptake
Cost and Funding Source	High; Incentives for Zero-Emission Vehicles Program, Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department; partner with Lanark Transportation
Start Time	In progress; 2023
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of new electric vehicles, # of municipalities utilizing funding
Expected GHG Reduction	Direct; High

GOAL 1.3 - Explore the use of low-carbon fuels (e.g., biodiesel blends) in suitable municipal fleet vehicles	
Recommended Approach	Connect with municipalities who use biodiesel to reduce greenhouse gas emissions (e.g., City of Brampton, York Region, Guelph, Kingston etc.)
	Combine local municipalities' procurement needs for biodiesel for use in heavy-duty diesel fleets
Potential Benefits	Reduce fossil fuels
Cost and Funding Source	To be determined
Person or Department Responsible	Climate and Environmental Department and local municipalities
Start Time	In progress; 2023
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Completion of feasibility study, # of participating vehicles, # of liters procured/used
Expected GHG Reduction	Direct; Medium

GOAL 1.4 – Update the Transportation Master Plan to include active transportation	
Recommended Approach	Encourage active transportation (e.g., walking and cycling) by coordinating and expanding accessible trails, comfortable walking routes, safe pedestrian crossing, and cycling infrastructure such as connecting trails and paved shoulders
	Facilitate policy changes to create 15-minute communities that are less car-dependent than conventional subdivisions
	Partner with school boards to create walking school bus program
Potential Benefits	Reduce fossil fuels, improve public health and accessibility
Cost and Funding Source	Medium; Public Works Budget
Person or Department Responsible	Public Works, Planning Department, CAO, local municipalities, partner with health unit
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	km of trails, km of paved shoulders, # of policies/plans changed or incorporated
Expected GHG Reduction	Indirect; Low

GOAL 1.5 - Reduce single occupancy automated vehicle trips by providing local transit, carpooling and ridesharing solutions suitable for rural communities	
Recommended Approach	Establish a Transportation Working Group to investigate and plan to adopt innovative public transit systems that are being implemented in similar small towns and rural communities
	Launch a County-wide carpool program that also encourages carpooling by promoting and strengthening the local carpool lot network
Potential Benefits	Reduce fossil fuels, improve accessibility
Cost and Funding Source	High; Green Municipal Fund Capital Funding, Infrastructure Canada Rural Transit Solutions Fund
Person or Department Responsible	Chief Administrative Officer, Climate and Environmental Department; partner with Lanark Transportation
Start Time	In progress; 2023
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Development of working group, Community Carpool website data
Expected GHG Reduction	Direct; Medium

Theme 2 – Buildings and Energy

Residential, commercial, industrial, and institutional buildings are responsible for 21.9% of community emissions, largely due to the use of natural gas. Due to the age of the housing and building stock in Lanark County, there is an opportunity for deep retrofits to improve energy efficiency and affordability for home-owners, tenants, and building-owners, while also reducing greenhouse gas emissions.

As communities are expected to experience more frequent incidents of extended power outages due to severe weather, increasing access to renewable energy in buildings and homes will be key to climate change adaptation.

GOAL 2.1 - Develop and support the delivery of a local home energy retrofit program including those offered by partner non-profits and private companies	
Recommended Approach	Investigate and develop a municipal loan or municipally led financing program for deep energy retrofits
	Organize energy retrofit training sessions and workshops for contractors and residents
	Update the list of energy efficiency programs on the County website
	Establish neighborhood action networks to advise homeowners on actions they can take to improve the energy efficiency of their homes
Potential Benefits	Reduce fossil fuels, increase energy efficiency, reduce costs, improve home comfort, increase participation in programs and incentives
Cost and Funding Source	High; Green Municipal Fund Capital Funding, County Budget, Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, Climate Network Lanark, Chief Administrative Officer
Start Time	In progress; 2023
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Amount of funding secured/allocated, launch of program, # of participants, # of trainings supported, # of homeowners engaged
Expected GHG Reduction	Direct; High

GOAL 2.2 - Establish a campaign to increase energy/water retrofits within the industrial, commercial, and institutional sector	
Recommended Approach	Raise awareness of available funding opportunities for energy/water retrofits
Potential Benefits	Reduce fossil fuels, increase energy efficiency, reduce costs, increase participation in programs and incentives
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate and Environmental Department
Start Time	2025
Approximate Timeframe for Completion	Short-term
Key Performance Indicators	# of businesses and industries engaged, # of retrofits completed
Expected GHG Reduction	Indirect; High

GOAL 2.3 - Establish green building standards that enforce climate resilient and adaptive building designs to increase energy efficiency and reduce greenhouse gas emissions	
Recommended Approach	Provide incentives and/or recognition to builders and building owners for achieving high performing energy and water efficiency standards
	Stimulate the development of high-performance new building construction towards net-zero
Potential Benefits	Reduce fossil fuels, reduce energy cost, stakeholder, and community engagement
Cost and Funding Source	Medium; Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, Planning Department, Local municipal planners, partner with Lanark Leeds Home Builders Association and developers
Start Time	To be determined
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Development of green building standards
Expected GHG Reduction	Indirect; High

GOAL 2.4 - Encourage solar photovoltaics (PV) developments where suitable (for net metering and microgrids) and solar thermal for domestic hot water use	
Recommended Approach	Identify underutilized County, municipal, or private lands and buildings that could be suitable for solar PV (e.g., large parking lots, industrial/business parks, brownfields)
	Connect with local renewable energy co-ops for financing and local investment opportunities
Potential Benefits	Reduce fossil fuels, reduce energy costs, increase renewable energy generation, increase climate resiliency
Cost and Funding Source	Medium; Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department, Planning Department, CAO, Partner with Independent Electricity System Operator (IESO) and Hydro One
Start Time	2025
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of feasibility study, # of areas identified
Expected GHG Reduction	Direct; High

GOAL 2.5 - Explore opportunities to utilize other renewable energy sources and technologies	
Recommended Approach	Engage and provide information to citizens on renewable fuel sources and technologies they can utilize
	Explore cooperative purchasing approaches to procure a regional supply of renewable energy (e.g., renewable natural gas (RNG), solar, wind)
Potential Benefits	Reduce fossil fuels
Cost and Funding Source	Medium; Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of feasibility study, # of people engaged
Expected GHG Reduction	Indirect; High

QUICK FACT:

Looking to do deep retrofitting or switch to greener energy? Check out our Retrofitting and Green Energy page for a list of incentives, resources, and local service providers: Retrofitting and Green Energy - Lanark County

Theme 3 – Natural Heritage and Resources

Natural features, including wetlands, forests, and other green spaces are important carbon sinks. These spaces also play an important role in climate adaptation as they offer essential services including stormwater management, water filtration, air quality improvements, and heat reduction. Protecting and increasing the coverage of these features across Lanark County is critical as the impacts of climate change are expected to negatively influence biodiversity and ecosystem services.

In the most recent report of the Ontario Provincial Climate Change Impact Assessment, Eastern Ontario is expected to experience high climate related risks associated with livestock and crop production by 2050[22]. Diversifying our local food system and helping farmers adapt to our changing environment is fundamental to supporting local food security and sovereignty. This section summarizes the approaches that the County will take to protect and improve both natural heritage and agriculture in Lanark County

GOAL 3.1 - Increase the managed forested area and tree canopy within Lanark County	
Recommended Approach	Collaborate with local municipalities to create an urban forest/reforest strategy (e.g., Lanark County 1 Million Trees Program) and/or a tree preservation policy
Potential Benefits	Sequester carbon, protect natural resources, increase forest cover, improve public health and access to greenspace, improve biodiversity
Cost and Funding Source	Medium; Climate Change Budget, local municipal budgets, Federal Two Billion Trees Program
Person or Department Responsible	Climate and Environmental Department, County Planner, and local municipalities; Partner with RVCA and MVCA
Start Time	In progress; 2020
Approximate Timeframe for Completion	Mid-term
Key Performance Indicators	Area of managed forest, # of trees planted, development of strategy and/or policy
Expected GHG Reduction	Indirect; Medium (carbon offsets)

22 Government of Ontario (2023), Ontario Provincial Climate Change Impact Assessment Ontario Provincial Climate Change Impact Assessment Technical Report - January 2023

GOAL 3.2 - Protect the carbon sequestration and climate resilience value of wetlands, greenspaces, and other naturalized areas within the County	
Recommended Approach	Work with local municipalities, Indigenous Peoples, agencies, NGOs, and others to identify, map, assess, protect, restore, manage and monitor natural heritage systems (i.e., wetlands, forests, lakes, etc.) where a key approach is to strengthen related land use policies and practices
	Work with local Conservation Authorities, NGOs, and lake associations to protect watershed health (i.e., through promotion of stewardship practices, water resources management, hazard mitigation, land-use planning, and drinking water source protection)
	Promote backyard pollinator habitat creation with native plants to protect native biodiversity and store carbon in the soil
	Protect and restore areas that have high carbon sequestration and biodiversity values by providing funding and resources to support local organizations committed to supporting landowner stewardship (e.g., ALUS Lanark)
Potential Benefits	Sequester carbon, protect natural resources, increase forest cover, improve public health and access to greenspace, improve biodiversity
Cost and Funding Source	Medium; Climate Change Budget, Public Works Budget
Person or Department Responsible	Climate and Environmental Department, County Planner, and local municipalities; Partner with RVCA, MVCA, Ducks Unlimited, Climate Network Lanark, The Land Between, Lake Associations, Canadian Wildlife Federation, ALUS
Start Time	In progress; 2023
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of acres protected, # of acres restored, # of people engaged, # of ALUS projects supported
Expected GHG Reduction	Indirect; Medium (carbon offsets)

GOAL 3.3 - Include the use of green infrastructure and natural heritage to serve local needs as the County continues to develop	
Recommended Approach	Encourage urban design and redevelopment approaches that incorporate natural systems and green infrastructure into site improvements, greenspaces, and stormwater management
Potential Benefits	Sequester carbon, protect natural resources, restore degraded land, improve landscape connectivity, prevent carbon loss from land use change, improve biodiversity, improve climate change mitigation, preserve and/or improve ecosystem services
Cost and Funding Source	Medium; Climate Change Budget, local municipal budgets, Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department, County planner, local municipalities; partner with The Land Between and Ducks Unlimited Canada
Start Time	2026
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of sites with green infrastructure
Expected GHG Reduction	Indirect; Low

GOAL 3.4 - Allow cooperative farming and community gardening on suitable County-owned lands and encourage local farms to produce more food for local consumption	
Recommended Approach	Encourage local farms to produce more food for local consumption by advocating for funding and municipal by-laws that support local food storage infrastructure, abattoirs, food processing, and on-farm slaughter
	Identify County, municipal, and private lands available for cooperative farming and community gardening
Potential Benefits	Produce local food for local consumption, reduce food transportation emissions, farmer engagement
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, Chief Administrative Officer, partner with local organizations
Start Time	2026
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	# of sites established, # of people engaged
Expected GHG Reduction	Indirect; Low

GOAL 3.5 - Promote the adoption of sustainable livestock and crop management practices	
Recommended Approach	Advance ecological, regenerative agriculture and livestock management practices through some form of public-private partnership
	Explore options to provide training and/or agronomic consultation
	Seek and support financial supports for farmers to invest in no-till agriculture equipment
Potential Benefits	Sequester carbon, protect natural resources, restore degraded land
Cost and Funding Source	Low, Climate Change Budget
Person or Department Responsible	Climate and Environmental Department; partner with agricultural organizations (e.g., ALUS Lanark)
Start Time	2026
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	# of farmers engaged, # of participants trained
Expected GHG Reduction	Indirect; Medium
GOAL 3.6 - Promote biogas energy recovery for use in aerobic digestion - combined heat and power (AD-CHP) systems on farms	
Recommended Approach	Explore the creation of a biogas farmers' cooperative and other strategic partnerships that aim to increase education and affordability of implementing these types of systems
Potential Benefits	Sequester carbon
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, partner with farmers and Canadian Biogas Association
Start Time	2026
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of feasibility study
Expected GHG Reduction	Indirect; Low

Theme 4 – Waste Diversion and Management

Waste only accounts for 3.2% of Lanark County's community emissions. However, emissions from the waste sector are projected to grow the most proportionally from 2019 – 2050 when compared to other sectors due to the roughly one-to-one relationship between population growth and waste production. In Lanark County, each local municipality is responsible for managing the waste produced in their community. Lanark County will continue to assist local municipalities and community members in improving their waste management practices to support a circular economy.

GOAL 4.1 - Identify sustainable solid waste and recycling solutions for municipalities	
Recommended Approach	Conduct a waste audit that includes all organic materials and recyclables and evaluates GHG produced in the transportation of materials to the waste sites
	Divert municipal solid waste from landfills by investigating waste conversion or recycling solutions such as Sustane Technologies Inc. proposal to build a facility in Renfrew County
	Launch soft plastics recycling system
	Explore recycling programs for renewable technology components at the end of their life (e.g., solar panels, batteries)
Potential Benefits	Divert solid waste and recyclables from landfills, reduce methane production, sustainable waste management, community engagement
Cost and Funding Source	Medium; local municipal budgets, Climate Change Budget, Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department, Chief Administrative Officer, local municipalities
Start Time	2025
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of local municipal waste audits, amount of waste diverted, # of participants in recycling program
Expected GHG Reduction	Direct; Medium

GOAL 4.2 - Optimize organic waste diversion	
Recommended Approach	Explore opportunities to improve organic waste diversion and provide compost and resources to residents, businesses, farmers, and other stakeholders (e.g., fungal dominant compost, biochar, yard waste, scrap wood)
	Promote online platforms that allow residents, farmers, and businesses to connect with people in Lanark County who will receive and compost their organic waste (e.g., Sharewaste)
	Create a unifying plan for organic waste management systems that benefits from a large reach/bulk buying and that promotes additional household organic waste management systems (e.g., Pay As You Throw)
	Broker food rescue partnerships between social organizations, farms, and food industries through organizations such as Second Harvest, which also offers funding
Potential Benefits	Divert organic waste from landfills, reduce methane production, community engagement, reduce municipal costs
Cost and Funding Source	Medium; Climate Change Budget, local municipal budgets, Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department, local municipalities
Start Time	In progress; 2023
Approximate Timeframe for Completion	Ongoing
Key Performance Indicators	Tonnes of organic waste diverted, # of participating municipalities
Expected GHG Reduction	Direct; Medium

GOAL 4.3 - Explore utilizing organic waste and treated biosolids for 3rd party Renewable Natural Gas (RNG) production	
Recommended Approach	Identify regional opportunities for Lanark County municipalities to participate in RNG production
Potential Benefits	Reduce fossil fuels, renewable fuel
Cost and Funding Source	Low; Climate Change Budget
Person or Department Responsible	Climate and Environmental Department, local municipalities, partner with Enbridge
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of feasibility study
Expected GHG Reduction	Indirect; Medium
GOAL 4.4 - Advance combined heat and power in anaerobic waste and water treatment facilities	
Recommended Approach	Explore the feasibility of utilizing biogas fueled combined heat and power systems for energy use on site in waste and water treatment facilities
Potential Benefits	Reduce fossil fuels, renewable fuel
Cost and Funding Source	Low; Climate Change Budget, local municipal budgets, Green Municipal Fund Capital Funding
Person or Department Responsible	Climate and Environmental Department and local municipalities
Start Time	2026
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Completion of feasibility study
Expected GHG Reduction	Indirect; Low

QUICK FACT:
In 2015, Ontarians generated about 3.7 million tonnes of food and organic waste, which includes food that could have been eaten or repurposed, as well as unavoidable waste, such as food scraps and vegetable peelings. Approximately 60% of this organic waste was sent to landfills, where it produces methane, a powerful greenhouse gas. Diverting organic waste through means of composting is a great way to reduce waste and generate soil! To learn more about how to compost visit: Take Action!-Lanark County

Theme 5 - Planning

Climate change adaptation means planning for and acting on the anticipated impacts of climate change. By taking action to plan for and adapt to the changing climate, Lanark County can build a stronger and more resilient community. To build momentum, it is imperative that policies, plans, and processes include climate change considerations. Updating existing plans to reflect the risks associated with climate change and the importance of natural infrastructure in adaptation and mitigation will help inform decision making and create a community that is resilient to climate change.

GOAL 5.1 - Incorporate climate change into County and municipal plans	
Recommended Approach	Consult with Indigenous communities on future revisions of Asset Management Plans to include natural assets (e.g., watersheds, wetlands, forests)
	Update Emergency Plans to include protocols for major natural disasters and weather events (i.e., evacuation routes, shelter locations)
	Develop a strategy to create an inclusive adaptation plan that captures risks and vulnerabilities to climate change (e.g., health, food security/sovereignty, environmental hazards, improved land-use, safety measures)
Potential Benefits	Better preparedness for the future, increased transparency, inclusivity, and consideration
Cost and Funding Source	Low; County budget, Climate Change Budget, FCM (Municipal Asset Management Program)
Person or Department Responsible	Climate and Environmental Department, Planning Departments of the County and local municipalities, LGLDHU, CAO, RVCA, MVCA, community stakeholders
Start Time	2024
Approximate Timeframe for Completion	Long-term
Key Performance Indicators	Number of County and municipal plans revised with climate change as a consideration
Expected GHG Reduction	Indirect; Low

ACTIONS YOU CAN TAKE

Reducing greenhouse gas emissions requires both large and small actions from individuals. Across Lanark County, individuals can take action to reduce the climate impact of their transportation, their home and kitchen, yard and greenspace, belongings, and day to day activities. Some key actions include:

Greening your transport through active transportation, carpooling, and/or purchasing an electric or hybrid vehicle when it's time to replace your vehicle.

Improving your home's energy efficiency by completing various home retrofits including upgrading your windows and doors, adding insulation, switching your heating system, etc..

Naturalizing your yard by reducing the area of maintained lawn or by planting native trees and other plants.

Reducing your waste by purchasing only as much as you need, buying second-hand or renewable products, composting your organic waste, and purchasing locally.

Getting involved in community groups to inspire local change and mobilize climate action.

Staying informed on local, provincial, national, and international climate action to help you understand what can be done to address climate change.

For a list of tangible actions you can take, please visit our website: https://www.lanarkcounty.ca/en/environmental-initiatives/Take_Action_.aspx.

"While the problem can sometimes seem overwhelming, we can turn things around — but we must move beyond climate talk to climate action."

— Ted Turner

IMPLEMENTING
THE PLAN

Key Implementation Strategies

Lanark County is moving forward to develop and implement the actions outlined in the Lanark County Climate Action Plan. To successfully implement the Climate Action Plan, see reductions in our corporate and community greenhouse gas emissions, and overcome barriers, implementing the plan requires a strategic approach.

In 2019, the Clean Air Partnership released a report on the main drivers and barriers to the implementation of municipal Climate Action Plans in Ontario[23]. The report identified five primary cross-sectoral drivers of climate action implementation: funding, community partnerships, staff capacity, institutionalizing climate action, and the strategic prioritization of climate initiatives. This report also identified low-climate literacy as one of the main barriers to successful implementation of Ontario municipalities' Climate Action Plans.

Lanark County will adopt six main implementation strategies to successfully implement the Lanark County Climate Action Plan. Five of the implementation strategies align with the implementation drivers identified by the Clean Air Partnership and one strategy is focused on community engagement and education to ensure that the Lanark County Climate Action Plan remains community-centered:

Leveraging funding
Building community partnerships
Increasing staff capacity
Institutionalizing climate action
Strategically prioritizing climate initiatives
Effectively engaging and educating community

Leveraging Funding

Securing funding is a critical driver of successful climate action implementation as identified by the Clean Air Partnership. Lanark County will implement the Climate Action Plan by leveraging available funding programs from the federal and provincial governments, as well as third-party organizations.

Examples of available funding programs that Lanark County can capitalize on to support climate initiatives include:

- *Natural Resources Canada - Zero Emission Vehicle Infrastructure Program*
- *FCM - Green Municipal Fund*
- *Government of Canada – Disaster Mitigation and Adaptation Fund*
- *Government of Canada – Rural Transit Solutions Fund*
- *FCM – Municipal Asset Management Program*

Lanark County will also advance the implementation of climate initiatives by educating community members, businesses, and local organizations on available funding and incentive opportunities. These may include funding opportunities from federal and provincial governments, conservation authorities, and organizations such as Enbridge Gas and Hydro One. A list of active funding programs is provided in Appendix C. The list is subject to change over time. Lanark County will continue to monitor and seek funding as more opportunities become available.

23 Clean Air Partnership (2019), Assessing the State of Climate Action in Ontario Municipalities: Drivers and Barriers to Implementation Report. https://www.cleanairpartnership.org/wp-content/uploads/2019/04/Drivers-and-Barriers-to-Implementation-Report-V4.pdf

Building Partnerships

To effectively implement climate initiatives and reduce greenhouse gas emissions, climate action needs to be a shared responsibility between local governments and community organizations such as utilities groups, non-governmental organizations, conservation authorities and groups, educational institutions, and other interested parties. Developing long-term partnerships, whether local in origin or expanding beyond the County, is key to effective implementation of municipal Climate Action Plans as they leverage the skills and expertise of the partner organization.

Establishing strong community partnerships maximizes efficiency, reach, cost-effectiveness, and credibility of climate initiatives. As climate initiatives are implemented from the Lanark County Climate Action Plan, we will work to develop community partnerships to help expand their reach and success. Examples of potential community partners include:

- *Utilities groups*
- *Community groups*
- *Non-profit organizations*
- *Local schools*
- *Conservation authorities*
- *Local businesses and associations*
- *Academic institutions*
- *Other municipalities*

The following partnerships have already been developed and can continue to expand over the implementation period: Climate Network Lanark, ALUS Lanark, EnviroCentre, Sustainable Kingston, and Greenscale. Lanark County will continue to maintain these partnerships while seeking additional opportunities to further enrich climate initiatives.

While implementing the Lanark County Climate Action Plan, it will also be critical to stay informed about ongoing innovation, funding opportunities, and technological developments through organizations such as the Clean Air Partnership, Canadian Green Building Council, Efficiency Canada, and QUEST Canada, as well as other sectoral stakeholders and academic institutions.

Increasing Staff Capacity

Having adequate municipal staff to coordinate climate initiatives, liaise with community partners, coordinate outreach, raise awareness of ongoing climate programs, and apply to and administer grants is integral to successfully implement the Lanark County Climate Action Plan. Dedicated climate staff will also increase the capacity to integrate greenhouse gas reduction objectives into a greater number of municipal policies, plans, and programs.

It is recommended that County Council continue to support the funding for the Climate and Environmental Department, as it is integral to the successful implementation of the Climate Action Plan. As increasing staff capacity may be a limitation of some municipalities, the County is committed to providing support and guidance as they navigate the creation of their own corporate and community climate action plans. Additionally, County Council should consider allocating a portion of the budget to a grant administrator dedicated to monitoring, selecting, and applying for applicable funding streams. Due to the time-intensive nature of securing and monitoring funded projects, it is noted by other Ontario municipalities that having a grant administrator has been advantageous to the success of their climate action plans[24].

24 Ibid 24

Institutionalizing Climate Action

Embedding Lanark County's commitment to climate action into formalized plans, policies, and decision-making processes will be key to implementing the Climate Action Plan. Without this level of accountability, the Climate Action Plan poses the risk of being seen as separate from core business activities and decisions. The adoption of the Lanark County Climate Lens was the first step in incorporating climate change risks and impacts into Council decisions. The Climate Lens was designed to make climate change a local municipal priority, make staff and councilors aware of the climate impact of their decisions, and increase the transparency of decision-making.

Moving forward, Lanark County can further institutionalize climate action by incorporating climate goals and initiatives into relevant official plans and budgets; for example, those relating to land-use, asset management, development, adaptation, and emergency planning. These plans often have strong overlap with Climate Action Plans and can act as official support to its implementation.

To keep the Climate Action Plan relevant and continuous, staff from the Climate and Environmental Department will regularly report to Council on progress and accomplishments. The Climate Action Plan will also be reviewed every two years to stay up to date with current technological developments and opportunities.

Strategically Prioritizing Climate Initiatives

To effectively manage the implementation of the Lanark County Climate Action Plan and use resources efficiently, it is necessary to prioritize a subset of climate initiatives to focus efforts and resources on for each Council term. Prioritizing climate initiatives makes it easier to secure funding, gain wider support from decision makers, and maximize climate benefits[25].

Effectively engaging and educating community

Throughout the duration of the implementation of the Climate Action Plan, Lanark County staff will work with community partners to continuously raise awareness of climate change and its impacts, ongoing climate initiatives, and opportunities for involvement including public funding opportunities. A communication strategy will need to be developed collaboratively with community partners and the Climate Action Working Group. Similarly, at the planning stage of each goal, an engagement plan will be created. These will include key messaging and communications approaches for various audiences including the general public, local municipalities, community organizations, and local businesses. Examples of engagement avenues include annual meetings, an online presence (i.e., website and social media), traditional media, working with existing networks and organizations, training programs, and public events. Hiring a communications coordinator could be beneficial regarding the long-term engagement of this plan.

25 Ibid 24

Priority Goals

To respond quickly and effectively to the climate crisis, Lanark County will prioritize eight major climate initiatives for the current Council term (2023 – 2026). As on-road transportation represents the majority (63%) of community greenhouse gas emissions and 27.3% of corporate emissions, a significant amount of County effort and resources will be directed towards reducing emissions within the transportation sector.

Advance transportation demand management programming and infrastructure

Improve energy efficiency of existing buildings

Optimize organic waste diversion

Support the adoption of electric vehicles and equipment

Transition to low-carbon transportation when electric is not a viable solution

Sequester carbon and protect natural resources

Increase the use of local and renewable energy generation and security

Create a climate conscious community culture

The 8 priority climate initiatives encompass 10 priority community goals and 4 priority corporate goals that will be focused on for the current Council term (Table 1). New goals will be prioritized as time progresses and priorities are achieved.

Table 1. Priority climate initiatives and goals for the current Council term (2023-2026).

Major Climate Initiative	Priority Community Goal	Priority Corporate Goal
Advance transportation demand management programming and infrastructure	1.4 Update the Transportation Master Plan to include active transportation	N/A
	1.5 Reduce single occupancy automated vehicle trips by providing local transit, carpooling, and ridesharing solutions suitable for rural communities	
Improve energy efficiency of existing buildings	2.1 Develop and support the delivery of a local home energy retrofit program including those offered by partner non-profits and private companies	2.5 Optimize heating and cooling efficiency in all County buildings to reduce energy consumption
	2.2 Establish a campaign to increase energy/water retrofits within the industrial, commercial, and institutional sector	3.2 Complete energy audits to identify the most effective energy-saving opportunities and prioritize projects when possible
Optimize organic waste diversion	4.2 Optimize organic waste diversion	N/A
	4.3 Explore utilizing organic waste and treated biosolids for third party renewable natural gas (RNG) production	N/A
Support the adoption of electric vehicles and equipment	1.1 Increase electric vehicle uptake and local charging infrastructure for public access	4.1 Upgrade 16 gas and 3 diesel fleet vehicles to electric vehicles by 2030 when electric vehicles are available/vehicles reach end of life
	1.2 Electrify municipal and community fleet vehicles as part of their replacement cycle	4.3 The procurement of any replacement or new equipment and power tools be electric, unless an electric option is not available
Transition to low-carbon transportation when electric is not a viable solution	1.3 Explore the use of low-carbon fuels (e.g., biodiesel blends) in suitable municipal fleet vehicles	Community goal 1.3 includes Lanark County corporate fleet
Sequester carbon and protect natural resources	3.1 Increase the managed forested area and tree canopy within Lanark County	N/A
	3.2 Protect the carbon sequestration and climate resilience value of wetlands, greenspaces, and other naturalized areas within the County	
Increase the use of local and renewable energy generation and security	2.5 Explore opportunities to utilize other renewable energy sources and technologies where feasible	N/A
Create a climate conscious community culture	To be integrated into all climate initiatives through the development of an engagement strategy.	

Oversight and Governance

County Council will be responsible for adopting the Climate Action Plan and supporting the implementation of climate initiatives. The Climate and Environmental Department will continue to oversee the implementation of the plan and will encourage local municipalities to either adopt or develop their own community Climate Action Plan and create their own corporate Climate Action Plans. The Climate and Environmental Department will also be responsible for liaising with community partners, raising public awareness of climate initiatives, and seeking funding. The Climate Action Working Group will continue to provide direction for the implementation of the plan during the current Council term.

Monitoring and Reporting

Monitoring the implementation of the Climate Action Plan will be critical in reaching the emission reduction targets by allowing us to understand the impact of climate initiatives and allocate resources accordingly.

Progress on each goal can be measured broadly through energy and greenhouse gas emission data, as well as through key performance indicators (KPI) specific to each goal. Example KPI include energy usage data, engagement data (e.g., number of participants in events or projects, number of people reached), and policy development, among others. KPI have been identified for each community and corporate goal. More specific and tailored KPI will be identified during the planning stage of each goal. Collecting empirical data throughout the implementation period will also be necessary to quantify the impact of actions.

Progress of the Climate Action Plan will be reported regularly to the Climate Action Working Group at the bimonthly meetings. An annual progress report of the Climate Action Plan will be provided to County Council and made available to the public at the end of each year. This report will outline:

- *Progress on key initiatives (e.g., stage of implementation, next steps, etc.)*
- *Barriers*
- *Summary of key performance indicators and data (if available)*
- *Projected timelines*

The Climate Action Plan will be reviewed every two years. These reviews will include an inventory update and a review of emission reduction targets. These reviews will also provide an opportunity to adjust the plan through the addition of new goals and removal of those that have been completed. The update and revisions of this plan will ensure that the plan remains relevant with new information and advancements in technologies and continues to reflect the evolving needs of the community.

CHALLENGES AND LIMITATIONS

Understanding the challenges and limitations of the Climate Action Plan and climate action in general can provide those responsible for implementation and community members with an understanding of the barriers to overcome during the implementation process. Although some of these limitations may improve as the plan is implemented, some will limit the feasibility of certain goals. As new limitations present themselves over the implementation period, staff will work with the Climate Action Working Group and community partners to reach viable solutions.

Greenhouse Gas Accounting

All estimates of Lanark County's greenhouse gas emissions are based off the best available data. Increasing the accuracy of greenhouse gas sources and sinks will be an important part of monitoring and the continued improvement of the plan.

Carbon Sequestration

Although there is sufficient research on understanding the carbon sequestration potential of trees and forests, there is limited data on the carbon sequestration potential of wetlands. Additionally, Lanark County's tree planting and pollinator habitat initiatives need to be assessed in greater detail as they relate to offsetting carbon. Having a more thorough understanding of how Lanark County's natural heritage offsets greenhouse gas emissions will be valuable in improving our future greenhouse gas inventories and reaching long-term climate targets.

Measurability of Climate Initiatives

Some initiatives in the Climate Action Plan will require time to gain traction and show a noticeable impact in the emission inventory. Implementing these actions early in the plan will be important but may not yield high reductions by the mid-term target year (2030). Additionally, implementing certain actions may not result in a measurable decrease in greenhouse gas emissions. For example, education, while integral to the ultimate success of climate initiatives, will pose a challenge in terms of quantifying its impact.

Geography and Population Density

Due to its size and population density, Lanark County faces various challenges in implementing climate initiatives. The dispersed settlement patterns of Lanark County make it highly dependent on vehicles for transportation, making it challenging to implement climate initiatives within the transportation sector and effectively reduce single passenger travel. Other challenges in climate action typical of smaller municipalities include the limited financial resources to develop, implement, deliver, and monitor climate initiatives; and the inability to draw upon the expertise and resources present in larger urban centres, making them more dependent on external consultants[26]. Lanark County is available to assist local municipalities where possible in the development and implementation of their climate action plans. The rural nature and size of municipalities in Lanark County will continue to be addressed throughout the implementation and revision stages of the Climate Action Plan.

Capacity of the Electrical Grid

According to the Independent Electricity System Operator (IESO), Ontario has entered a period of increasing electricity demand after years of declining consumption[27]. The IESO forecasts an annual demand increase of almost two percent over the next 20 years, with the primary drivers being developments in the industrial sector, in particular mining, steel, electric vehicle battery and hydrogen production; greenhouse construction in the agricultural sector; and electrification of the transportation sector. In combination, there is a decreasing electricity supply province-wide due to nuclear retirements and refurbishments, and expiring generation contracts. To address the increasing demand and decreasing supply, the IESO recognizes the importance of securing new energy generation and storage capacity. The IESO will continue to work with electricity sector partners to address future supply challenges in a timely, cost-effective, and flexible way. For more information on how the IESO plans on keeping up with the evolving electrical grid, visit their website at https://www.ieso.ca/en/Learn/The-Evolving-Grid/Securing-New-Energy-Supply.

26 Federation of Canadian Municipalities, Small and Rural Communities Climate Action Guidebook. https://assets-global.website-files.com/6022ab403a6b2126c03ebf95/607d839e9feb3a640fb82fd9_Small%20and%20Rural%20Communities%20Guidebook_EN.pdf **27** IESO (2022), Annual Planning Outlook. Ontario's electricity system needs: 2024-2043. Annual Planning Outlook (ieso.ca)

APPENDICES

Appendix A: Local Climate Projections

Climate and Temperature Projections

Climate and temperature projections are based on data obtained from the Climate Atlas of Canada (https://climateatlas.ca/), which is an interactive tool for citizens, researchers, businesses, and community and political leaders to learn about climate change in Canada. The Climate Atlas sources most of its data from the Pacific Climate Impacts Consortium (PCIC), which uses 24 climate models to project future climate conditions in response to two emissions scenarios – a low carbon scenario (RCP 4.5) and a high carbon scenario (RCP 8.5; Table 2).

Table 2: RCP 8.5 - High Carbon scenario for Lanark County

RCP 8.5: High Carbon climate future
GHG emissions continue to increase at current rates

Variable	Period	1976-2005 Mean	2021-2050 Low	2021-2050 Mean	2021-2050 High	2051-2080 Low	2051-2080 Mean	2051-2080 High
Precipitation (mm)	annual	866	772	924	1087	796	955	1134
Precipitation (mm)	spring	206	151	227	308	163	241	324
Precipitation (mm)	summer	220	145	225	308	139	220	308
Precipitation (mm)	fall	241	171	251	336	171	256	358
Precipitation (mm)	winter	200	152	221	298	168	238	320
Mean Temperature (°C)	annual	6.5	7.3	8.7	10.1	9.4	10.9	12.7
Mean Temperature (°C)	spring	5.7	5.2	7.6	10.2	7.1	9.6	12.5
Mean Temperature (°C)	summer	19.5	20.1	21.6	23	21.8	23.8	25.9
Mean Temperature (°C)	fall	8.5	9	10.7	12.5	10.9	12.7	14.6
Mean Temperature (°C)	winter	-7.9	-8.4	-5.5	-2.5	-5.8	-2.9	0
Tropical Nights	annual	4	5	13	24	15	31	50
Very hot days (+30°C)	annual	13	15	32	50	33	58	82
Very cold days (-30°C)	annual	1	0	0	1	0	0	0
Date of Last Spring Frost	annual	May 2	April 3	April 22	May 9	March 23	April 13	May 2
Date of First Fall Frost	annual	Oct. 3	Sep. 29	Oct. 18	Nov. 5	Oct. 10	Oct. 29	Nov. 19
Frost-Free Season (days)	annual	152	148	176	206	167	196	229

Community Business as Usual Forecast

The community business as usual forecast is based on the best available data showing an estimated 1.84% annual county-wide population growth rate for 2019. Since assuming a one-to-one relationship between population growth rate and all greenhouse gas inventory sectors likely overestimates future emissions, a series of assumptions were made when forecasting emissions (Table 3).

Table 3: Assumptions made to calculate the BAU scenario

GHG Inventory Sector	Assumptions	Net Impact on BAU forecast
Transportation	Newer internal combustion vehicles using gasoline and diesel are required to be made more fuel efficient over time due to existing federal standards and regulations affecting auto manufacturing.[28] This will help decrease fuel consumption per VKT.	Potential decrease in emissions by 1- 1.25% per year dampened to 0.75% per year due to increasing GHGs from electricity generation
Residential and ICI stationary energy	New equipment and appliances will be more efficient over time due to existing standards and regulations affecting their manufacturing. A similarly case exists for new buildings constructed to the provincial building code in comparison to historical construction.[29] This will help decrease natural gas and electricity consumption per capita and in local GDP. According to the IESO, the carbon intensity of the Provincial electricity grid is expected to double from 2019 – 2029 and quadruple by 2043. This increases the emission factors used in estimating GHGs from electricity consumption within Lanark.[30]	
Solid Waste/ wastewater	Assumed a one-to-one relationship with population growth in all BAU scenarios.	+1.84% per year
Agriculture (Livestock) / Forests	Area of agricultural land within the County has the potential to decrease over the next few decades due to expanding development as the population increases over time in all scenarios. It is also assumed there is no new managed forest area in any of the forecasts. These assumptions are the same in all four BAU scenarios.	0%

28 See CER – Market Snapshot: Vehicle emissions standards will reduce gasoline use (cer-rec.gc.ca) **29** See the Demand-Forecast-Module-Data within the Independent Electricity System Operator's (IESO) 2022 Annual Planning Outlook https://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual-Planning-Outlook **30** See IESO 2022 Annual Planning Outlook report (Figure 48) https://www.ieso.ca/en/Sector-Participants/IESO-News/2022/12/2022-Annual-Planning-Outlook

Appendix B: Cost and timeframe definitions

Each corporate and community goal includes information on cost and approximate timeframe for completion. The cost to the County will be dependent upon external funding and partnership opportunities. The definitions for each cost and timeframe category are as follows:

Cost

Low = < $10,000
Medium = $10,000 - $100,000
High = > $100,000

Approximate timeframe for completion

Short-term = 1-2 years
Mid-term = 3-6 years
Long-term = 7-10 years
Ongoing = more than 10 years

Appendix C: Available Funding Programs

The following lists of funding opportunities are not exhaustive and are subject to change. The lists will be revised with each revision of the Climate Action Plan to reflect the current opportunities available.

Table 4: Funding programs available for corporate actions

Funding Name	Provider	Description
Applicable Sector: Transportation and Equipment		
Electric Vehicle Incentive Program	Government of Canada	https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/light-duty-zero-emission-vehicles/incentives-purchasing-zero-emission-vehicles
Applicable Sector: Buildings and Energy		
Pilot project: Retrofit of municipal facilities	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-retrofit-municipal-facilities
Study: Retrofit of municipal facilities		https://greenmunicipalfund.ca/funding/study-retrofit-municipal-facilities
Capital project: Retrofit of municipal facilities		https://greenmunicipalfund.ca/funding/capital-project-retrofit-municipal-facilities
Study: New construction of energy-efficient municipal facilities	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-new-construction-energy-efficient-municipal-facilities
Pilot project: New construction of energy-efficient municipal facilities		https://greenmunicipalfund.ca/funding/pilot-project-new-construction-energy-efficient-municipal-facilities
Capital project: New construction of energy-efficient facilities		https://greenmunicipalfund.ca/funding/capital-project-new-construction-energy-efficient-facilities

Funding Name	Provider	Description
Capital project: Water conservation, municipal project	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-water-conservation-municipal-project
Pilot project: Water conservation, municipal project		https://greenmunicipalfund.ca/funding/pilot-project-water-conservation-municipal-project
Study: Water conservation, municipal project		https://greenmunicipalfund.ca/funding/study-water-conservation-municipal-project
Applicable Sector: Waste Management and Diversion		
Pilot project: Stormwater quality, municipal project	Green Municipal Fund	https://greenmunicipalfund.ca/funding/pilot-project-stormwater-quality-municipal-project
Study: Stormwater quality, municipal project		https://greenmunicipalfund.ca/funding/study-stormwater-quality-municipal-project
Applicable Sector: Lanark County Housing Corporation		
Affordable Multi-Family Residential Program	Enbridge	https://www.enbridgegas.com/business-industrial/incentives-conservation/programs-and-incentives/retrofits-custom-projects/affordable-multi-family-housing-program
Planning: Early support grant for sustainable affordable housing projects	Green Municipal Fund	https://greenmunicipalfund.ca/funding/planning-early-support-grant-sustainable-affordable-housing-projects
Study: Retrofit or new construction of sustainable affordable housing		https://greenmunicipalfund.ca/funding/study-retrofit-new-construction-sustainable-affordable-housing
Pilot project: Retrofit or new construction of sustainable affordable housing		https://greenmunicipalfund.ca/funding?page=2

Funding Name	Provider	Description
National Housing Co-Investment Fund: Renovation	Canadian Mortgage and Housing Corporation-	https://www.cmhc-schl.gc.ca/professionals/project-funding-and-mortgage-financing/funding-programs/all-funding-programs/co-investment-fund/co-investment-contribution-funding
Canada Greener Affordable Housing program		https://www.cmhc-schl.gc.ca/professionals/project-funding-and-mortgage-financing/funding-programs/all-funding-programs/canada-greener-affordable-housing-program
Deep Retrofit Accelerator Initiative	Government of Canada via Envirocentre	https://natural-resources.canada.ca/energy-efficiency/buildings/deep-retrofit-accelerator-initiative/24925

Table 5: Funding programs available for community actions

Funding Name	Provider	Description
Applicable Sector: Transportation		
For Municipalities		
Rural Transportation Fund	Government of Canada	https://www.infrastructure.gc.ca/rural-trans-rural/details-eng.html
Study: Transportation networks and commuting options	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-transportation-networks-commuting-options
Electric Vehicle Incentive Program	Government of Canada	https://tc.canada.ca/en/road-transportation/innovative-technologies/zero-emission-vehicles/light-duty-zero-emission-vehicles/incentives-purchasing-zero-emission-vehicles
Pilot project: Transportation networks and commuting options	Green Municipal Fund	https://greenmunicipalfund.ca/funding/pilot-project-transportation-networks-commuting-options
Capital project: Transportation networks and commuting options		https://greenmunicipalfund.ca/funding/capital-project-transportation-networks-commuting-options

Funding Name	Provider	Description
Applicable Sector: Transportation		
For Municipalities		
Study: Reduce fossil fuel use in fleets	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-reduce-fossil-fuel-use-fleets
Pilot project: Reduce fossil fuel use in fleets		https://greenmunicipalfund.ca/funding/pilot-project-reduce-fossil-fuel-use-in-fleets
Capital project: Reduce fossil fuel use in fleets		https://greenmunicipalfund.ca/funding/capital-project-reduce-fossil-fuel-use-fleets
Applicable Sector: Buildings		
For Homeowners		
Greener Homes Grant	Enbridge/ Government of Canada	https://natural-resources.canada.ca/energy-efficiency/homes/canada-greener-homes-initiative/canada-greener-homes-grant/canada-greener-homes-grant/23441
Renovate Lanark	Lanark County	https://www.lanarkcounty.ca/en/family-and-social-services/renovate.aspx
Home Winterproofing Program	Enbridge	https://www.enbridgegas.com/residential/rebates-energy-conservation/home-winterproofing-program#:~:text=Free%20energy%20upgrades%20for%20homes%20in%20need%20The,to%20reduce%20energy%20costs%20up%20to%2030%20percent.
Energy Affordability Program	Save on Energy	https://www.saveonenergy.ca/For-Your-Home/Energy-Affordability-Program
Net Metering	Ontario Government	https://www.ontario.ca/page/save-your-energy-bill-net-metering
Businesses and ICI		
Small Business Program	Save on Energy	https://saveonenergy.ca/en/For-Your-Small-Business/Programs-and-Incentives/Small-Business-Program
Existing Building Commissioning program		https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Existing-Building-Commissioning-Program
Strategic Energy Management program		https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Strategic-Energy-Management-Program
Industrial Energy Efficiency Program		https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Industrial-Energy-Efficiency-Program

Funding Name	Provider	Description
Applicable Sector: Buildings		
Businesses and ICI		
Energy Performance Program	Save on Energy	https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Energy-Performance-Program
Retrofit Program		https://saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Retrofit-Program/About
Foodservice distributor discount program		https://www.saveonenergy.ca/en/For-Business-and-Industry/Programs-and-incentives/Foodservice-Distributor-Discount-Program
Retrofits and Custom Projects	Enbridge	https://www.enbridgegas.com/business-industrial/incentives-conservation/programs-and-incentives/retrofits-custom-projects
Industrial Custom Engineering Program		https://www.enbridgegas.com/business-industrial/incentives-conservation/programs-and-incentives/retrofits-custom-projects/industrial-custom-engineering-program
Commercial Custom Retrofit Program		https://www.enbridgegas.com/business-industrial/incentives-conservation/programs-and-incentives/retrofits-custom-projects/commercial-custom-retrofit-program
For Municipalities		
Study: Design a local home-energy upgrade financing program	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-design-local-home-energy-upgrade-financing-program
Pilot project: Local home-energy upgrade financing program		https://greenmunicipalfund.ca/funding/pilot-project-local-home-energy-upgrade-financing-program
Study: Renewable energy production on a brownfield	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-renewable-energy-production-brownfield
Pilot project: Renewable energy production on a brownfield		https://greenmunicipalfund.ca/funding/pilot-project-renewable-energy-production-brownfield
Capital project: Renewable energy production on a brownfield		https://greenmunicipalfund.ca/funding/capital-project-renewable-energy-production-brownfield

Funding Name	Provider	Description
Applicable Sector: Buildings		
For Municipalities		
Study: Design a local home-energy upgrade financing program	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-design-local-home-energy-upgrade-financing-program
Pilot project: Local home-energy upgrade financing program		https://greenmunicipalfund.ca/funding/pilot-project-local-home-energy-upgrade-financing-program
Study: Renewable energy production on a brownfield	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-renewable-energy-production-brownfield
Pilot project: Renewable energy production on a brownfield		https://greenmunicipalfund.ca/funding/pilot-project-renewable-energy-production-brownfield
Capital project: Renewable energy production on a brownfield		https://greenmunicipalfund.ca/funding/capital-project-renewable-energy-production-brownfield
Capital project: Water conservation, community project	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-water-conservation-community-project
Study: Water conservation, community project		https://greenmunicipalfund.ca/funding/study-water-conservation-community-project
Pilot project: Water conservation, community project		https://greenmunicipalfund.ca/funding/pilot-project-water-conservation-community-project
Capital project: Energy recovery or district energy	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-energy-recovery-or-district-energy
Pilot project: Energy recovery or district energy		https://greenmunicipalfund.ca/funding/pilot-project-energy-recovery-or-district-energy
Study: Energy recovery or district energy		https://greenmunicipalfund.ca/funding/study-energy-recovery-district-energy

Funding Name	Provider	Description
Applicable Sector: Buildings		
Applicable Sector: Natural Heritage and Resources		
TD Friends of the Environment Foundation Grant	TD	https://www.td.com/ca/en/about-td/ready-commitment/funding/fef-grant
Capital project: Site remediation or risk management	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-site-remediation-or-risk-management
Study: Site remediation or risk management		https://greenmunicipalfund.ca/funding/study-site-remediation-or-risk-management
Pilot project: Site remediation or risk management		https://greenmunicipalfund.ca/funding/pilot-project-site-remediation-or-risk-management
Plan: Brownfield strategy or action plan	Green Municipal Fund	https://greenmunicipalfund.ca/funding/plan-brownfield-strategy-action
Capital project: Brownfield site redevelopment		https://greenmunicipalfund.ca/funding/capital-project-brownfield-redevelopment
Study: Brownfield site redevelopment		https://greenmunicipalfund.ca/funding/study-brownfield-site-redevelopment
Pilot project: Brownfield site redevelopment		https://greenmunicipalfund.ca/funding/pilot-project-brownfield-site-redevelopment
Study: Stormwater quality, community project	Green Municipal Fund	https://greenmunicipalfund.ca/funding/study-stormwater-quality-community-project
Capital project: Stormwater quality, community project		https://greenmunicipalfund.ca/funding?page=1
Pilot projects: Stormwater quality, community project		https://greenmunicipalfund.ca/funding/pilot-projects-stormwater-quality-community-project
ALUS Lanark	ALUS	https://alus.ca/alus_community/alus-lanark/
ECCC Funding Opportunities	Government of Canada	https://www.canada.ca/en/environment-climate-change/services/environmental-funding.html

Funding Name	Provider	Description
Applicable Sector: Buildings		
Applicable Sector: Waste Management and Diversion		
Capital project: Waste stream management	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-waste-stream-management
Study: Waste stream management		https://greenmunicipalfund.ca/funding?page=2
Pilot project: Waste stream management		https://greenmunicipalfund.ca/funding/pilot-project-waste-stream-management
Capital project: Waste stream management		https://greenmunicipalfund.ca/funding/capital-project-waste-stream-management
Capital project: Waste reduction and diversion	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-waste-reduction-diversion
Pilot project: Waste reduction and diversion		https://greenmunicipalfund.ca/funding/pilot-project-waste-reduction-diversion
Study: Waste reduction and diversion		https://greenmunicipalfund.ca/funding/study-waste-reduction-diversion
Capital project: Wastewater systems	Green Municipal Fund	https://greenmunicipalfund.ca/funding/capital-project-wastewater-systems
Pilot project: Wastewater systems		https://greenmunicipalfund.ca/funding/pilot-project-wastewater-systems
Study: Wastewater systems		https://greenmunicipalfund.ca/funding/study-wastewater-systems
Capital project: Septic wastewater systems		https://greenmunicipalfund.ca/funding/capital-project-septic-wastewater-systems
Applicable Sector: Planning		
Plan: Sustainable neighbourhood action plan	Green Municipal Fund	https://greenmunicipalfund.ca/funding/plan-sustainable-neighbourhood-action-plan

This is **Exhibit B** referred to in the affidavit of Susan Brandum
sworn or affirmed before me on July 25, 2025.

____
Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C

CANADIAN CLIMATE INSTITUTE
L'INSTITUT CLIMATIQUE DU CANADA

HEAT EXCHANGE

How today's policies will drive or delay Canada's transition to clean, reliable **heat for buildings**

JUNE 2024

Canadian Climate Institute | L'Institut climatique du Canada

HEAT EXCHANGE

How today's policies will drive or delay Canada's transition to clean, reliable **heat for buildings**

JUNE 2024

Kate Harland, Research Lead
Sachi Gibson, Mitigation Research Director
Jason Dion, Senior Research Director
Nikhitha Gajudhur, Research Associate
Kathleen Mifflin, Senior Research Associate

CONTENTS

EXECUTIVE SUMMARY

Any viable path to net zero for the buildings sector must ensure that Canadians have reliable access to affordable heating and cooling. And that means that the shift toward net zero requires not just changes in how individual buildings are heated and cooled, but also changes to energy systems more broadly and to the regulatory frameworks that govern them.

The economy-wide goal of net zero by 2050 is increasingly the frame for policy conversations in Canada and around the world. In Canada, energy utilities are only beginning to map out what the clean energy transition means for their systems and customers. Similarly, regulators and the governments that oversee them are only starting to contend with what the energy transition requires from them.

So far, inertia is prevailing. And without significant shifts in policy to enable and accelerate the transition to net zero in the buildings sector and the energy systems that serve it, continued inertia will result in higher costs, missed climate targets, or both.

This report seeks to facilitate progress by bringing clarity to these complex topics and by advising policy makers—particularly in provincial governments—on ways to accelerate the shift toward net zero buildings while protecting affordability and reliability.

Our analysis draws on multiple sources of data and evidence. We commissioned original modelling to identify pathways to net zero that minimize overall costs to the economy, and to surface important differences between provinces. We surveyed the literature to identify consistent patterns in what a cost-optimal pathway to net zero means for the buildings sector and for energy systems across the country. And we engaged with stakeholders and experts to solicit feedback on our assumptions and results, and adjusted inputs and sensitivity analyses in response. In parallel, we analyzed regulatory proceedings and inquiries throughout North America concerning gas utilities and the energy transition, and extracted data from utility filings to quantify growth in the gas network.

Based on this analysis, several insights emerge. Overall, the model's cost optimization consistently shows that achieving net zero in Canada will require a significant increase in the use of electricity for building heat, and a declining use of gas, starting right away.

Continued inertia poses risks to achieving Canada's climate goals and ensuring affordability and reliability through the energy transition.

Despite some recent progress, Canada's buildings sector and its electricity and gas systems are not yet on that cost-optimal net zero path. We find that this is unlikely to change under current policy and regulatory approaches, and that continued inertia poses risks to achieving Canada's climate goals and ensuring affordability and reliability through the energy transition.

Finding 1

On a cost-optimal pathway to net zero, electricity will power most space heating in Canada

The details vary from province to province, but the pattern is consistent across all regions and in all sensitivity scenarios: as Canada's energy transition accelerates, electricity will power more and more space heating in Canada. Heat pumps with electric resistance backup are often the most cost-optimal long-term pathway—even considering the significant electricity system build-out that they require. This finding is broadly consistent with other major Canadian and global studies that have investigated the same topic.

Mitigating peak demand to keep electricity affordable and reliable will likely emerge as the central challenge facing electric utilities in this transition. Our modelling finds that in the buildings sector, retrofits of existing buildings, the rising energy efficiency of new buildings, and the switch from electric baseboards to much more efficient heat pumps can all contribute to reducing the scale of the necessary electricity system build-out. Hybrid systems, which maintain existing gas connections as a backup to electric heat pumps, play a role in some contexts to mitigate peaks in winter electricity demand. And other options like heat and energy storage, thermal energy networks, and demand-side management will also likely play an important role.

Finding 2

Even with low-carbon gases or hybrid heat, continued expansion of the gas network is inconsistent with cost-effectively reaching net zero

Given the rapid shift away from gas consumption in buildings along a cost-optimal pathway to net zero, provinces that continue to expand their gas distribution networks risk significantly raising the cost of meeting climate targets, putting targets in jeopardy, or both. Additional expansion of the gas system to new homes or neighbourhoods is risky for ratepayers because it can lock in higher-cost ways of delivering heat to homes and businesses, or result in stranded assets that gas consumers must still pay off.

Hybrid heat (the pairing of heat pumps with gas furnaces) does not justify continued expansion of gas networks. Hybrid heat can be a legitimate stepping stone to full electrification in some contexts, and a viable long-term pathway in others—especially when furnaces are burning low-carbon gases. But because hybrid systems would only switch to gas in the coldest days or months, overall demand for gas would still fall dramatically, so expansion poses the same risks for ratepayers.

Likewise, low-carbon gases like hydrogen and biomethane will not serve as replacement fuels on a scale that can justify continued gas network expansion. Our modelling and numerous other studies find that these gases are either too scarce or too costly to heat more than a small fraction of Canada's buildings, and are instead taken up by other sectors such as heavy industry. Even under lower-cost assumptions for these fuels, electrification of building heat still dominates.

Finding 3

A business-as-usual approach to utility regulation is not in the interest of ratepayers

In the energy transition, gas utilities' incentives do not necessarily align with what is most affordable for ratepayers over the long term. Because gas utilities realize returns primarily on the infrastructure they install, rather than the fuel they sell, and because they earn a predetermined rate of return on regulator-approved capital investments, these entities have a direct economic incentive to pursue continued growth of gas infrastructure and new customers—even if the long-term usage case is uncertain.

The longer that regulators and policy makers delay action to overturn the status quo, the greater the risk that Canadians will end up on the hook for an overbuilt and underused gas system, an overburdened electrical grid, or both.

The job of an energy regulator is in part to protect ratepayers in an environment of utility monopolies, and the energy transition presents new challenges to their ability to deliver on this mandate. Their mandates—which are typically to ensure utilities provide safe and reliable energy at just and reasonable rates—were established before climate change was a societal concern, so it can be unclear how regulators should factor in climate goals and the changes underway in the energy transition. And while some provinces have set net zero goals into law, no province has sufficiently aligned its climate and energy policies with those goals. Because regulators are not in a position to make assumptions about future policy, many regulators have been understandably cautious in the face of this ambiguity. With some exceptions, regulators continue to approve gas network expansion.

Prudent, forward-looking utility regulation is more important than ever in the energy transition. The longer that regulators and the provincial policy makers who oversee them delay action to overturn the status quo, the greater the risk that Canadians will end up on the hook for an overbuilt and underused gas system, an overburdened electrical grid, or both.

Finding 4

Provincial and territorial policy is the missing piece for achieving climate goals while protecting reliability and affordability

If utility regulators are to continue delivering on their mandate of providing safe and reliable energy at just and reasonable rates, provincial governments must equip them to face the new challenges of the energy transition head-on. But no province has yet issued a long-term direction on what the clean energy transition means for the future of gas for building heat in their jurisdiction, nor mandated gas and electricity systems to transform to get on a cost-effective path to net zero.

This lag in provincial policy leadership carries significant consequences. Gas networks are continuing to expand, with buildings standing out as one of only two sectors of the Canadian economy where emissions continue to rise under current climate policies. And regulators are not adequately equipped to effectively oversee the energy transition. These two policy problems interact to keep energy systems on the wrong track.

Absent policy leadership, provinces risk ending up with underdeveloped or unbalanced energy systems that are not ready for what's coming, straining affordability and reliability.

Specific policy changes can put Canada on a net zero pathway that protects affordability and reliability. While a widespread shift in how Canadians heat their buildings will take place over decades, policymakers and regulators are making decisions today that will lay the groundwork out to 2050 and beyond. This report makes the following recommendations to help regulators and governments make decisions in the clean energy transition in a way that protects long-term energy affordability and system reliability for Canadians.

Recommendation 1

Provincial governments should equip regulators, system operators, and utilities to make decisions consistent with net zero

Provincial governments should clarify their policy objectives and ensure that energy system planning is aligned with the clean energy transition. They should:

- Legislate a target for net zero by 2050 as well as interim milestones, update mandates to include achievement of these climate targets, and equip regulators with the necessary financial and human resources.
- Commission and regularly update independent pathway assessments that unpack a jurisdiction's options for reaching net zero economy-wide, and the pros and cons of each option. These high-level assessments should complement, and ideally integrate, more granular pathway assessments undertaken by utilities and/or system operators.
- Produce energy roadmaps that present the government's vision for how the jurisdiction's technology and energy mix, and the infrastructure it will require, should evolve in line with net zero. In particular, roadmaps should specify the roles of the gas network and electricity grid through the transition and identify responsibilities for overall energy system coordination.

Recommendation 2

Provincial governments should stop treating gas system expansion as the default option, and equip regulators to consider alternatives

Across Canada, government policy should no longer treat the connection of new buildings to gas networks as a matter of course. In most contexts, and particularly for new developments, electrification should be the default, unless there is a specific local alternative such as a thermal energy network. The following policy actions could help reset this default:

- Provinces could immediately direct regulators to consider the risks of stranded gas assets when reviewing gas utility submissions, and weigh those risks against alternatives to replacing and extending gas pipelines.
- Provinces could also direct regulators to reform obligation-to-serve requirements for gas utilities, so they do not necessitate continued gas network expansion.
- Provinces could also mandate that new buildings be fully electric, except where a suitable net-zero alternative exists (such as a thermal energy network).

Recommendation 3

Provincial governments should require gas utilities to provide maps of their networks to facilitate a managed transition that protects ratepayers

Provincial governments, regulators, and gas utilities should start laying the groundwork for the gradual, managed contraction of gas networks. Mapping existing gas infrastructure is a foundational part of this proactive work. Canadian provinces can learn from other jurisdictions, including California, the Netherlands, and Germany, that have already pursued alternatives to new pipelines and begun selective, proactive gas network pruning based on detailed understanding of their gas grids.

Recommendation 4

All orders of government should strengthen policies to support building electrification, peak management, and energy efficiency

Consumer-focused climate policy should be strengthened alongside reforms to utility regulation. The suite of consumer-focused policies that should be strengthened includes: regulatory certainty (building codes, appliance standards); direct financial support for energy retrofits, smart electrification, and peak management (grants, financing); implementation support (labour market development, training); and a broad-based, consistent, and rising price on greenhouse gas emissions.

Recommendation 5

All orders of government should centre equity in policy design and provide targeted support to the most affected

As governments and regulators act to limit the extent of the infrastructure liabilities facing ratepayers, provincial policy must still determine who bears the unrecovered costs of stranded or underused energy infrastructure, and how. Governments should also help address the barriers that can prevent renters and low-income households from electrifying and accessing energy retrofits. Governments and regulators presiding over energy system changes should expect that there will be equity impacts, and proactively design solutions to address them.

INTRODUCTION

Affordable, reliable heating and cooling for Canadian buildings is a necessity, not an option, on the road to net zero. Delivering on that goal requires some big shifts from provincial governments, energy regulators, utilities, and Canadians. The stakes are high: a passive, reactive policy approach is a recipe for higher emissions, higher costs, or both.

The economy-wide goal of net zero by 2050 is increasingly the frame for policy conversations in Canada and around the world (*see Box 1*). For the buildings sector, reaching net zero means that Canadian policy must incentivize a gradual and steady shift toward clean heat.

Governments, utilities, and regulators are just starting to contend with the impact this transition will have on the vast network of gas pipelines buried beneath large parts of the country, as well as on Canada's electricity infrastructure.

Today, fossil fuels—primarily gas and, to a lesser extent, heating oil—feed the furnaces and boilers that heat nearly half of this country's homes (*NRCan 2020*) and an equivalent share of its commercial and institutional buildings (*NRCan 2023a*; *NRCan 2023b*). Transitioning to clean sources of heat will mean widespread changes at the scale of individual buildings and neighbourhoods: more efficient new buildings, energy retrofits on old buildings, and rising consumer uptake of efficient electric heat pumps, displacing the use of gas and oil.

Alongside these building-by-building changes, the clean energy transition will require transformative change at the scale of provincial energy systems. Governments, utilities, and regulators are just starting to contend with the impact this transition will have on the vast network of gas pipelines buried beneath large parts of the country, as well as the impact on Canada's electricity infrastructure.

This report focuses on that system scale: the energy systems that Canadians rely on to keep their homes and businesses warm. We explore how those systems, and the regulatory frameworks that govern them, must adapt for Canada to reach net zero in a way that minimizes costs for ratepayers, governments, and the economy as a whole.

Box 1

Aligning building heat with net zero

The drive to reach net zero in order to limit the damage from accelerating climate change increasingly drives policy and markets across Canada and around the world.

Canada has a legislated commitment to reach net zero by 2050 through the *Canadian Net-Zero Emissions Accountability Act*, which came into force in June 2021. Seven provinces and territories have Climate Accountability Acts that require the government to set emissions targets, establish a plan, and report on progress (*Linden-Fraser 2024*). Of these, Prince Edward Island (*Net Zero Carbon Act*), Nova Scotia (*Environmental Goals and Climate Change Reduction Act*), Yukon (*Clean Energy Act*), and British Columbia (*Climate Change Accountability Act*) have directly legislated their 2050 climate targets.[1] Quebec, New Brunswick, and Manitoba have a publicly stated goal of a carbon-neutral economy by 2050 (*Government of Québec 2023a; Government of New Brunswick 2022; Government of Manitoba n.d.*), and Alberta's emission reduction and energy development plan notes the province's aspiration of carbon neutrality by 2050 (*Government of Alberta 2023*).

Globally, too, net zero commitments are increasingly the norm, setting the context of the global economy. Countries committed to reaching net zero by mid-century generate 90 per cent of global GDP (*IEA 2023a*), including over 93 countries and the European Union. More than a third of the world's largest publicly traded companies now have net zero targets, including two thirds of Canada's largest businesses (*Net Zero Tracker 2022*). Industry associations from dairy farming to cement production have action plans to make their products carbon neutral, with interim milestones along the way (*Dairy Farmers of Canada n.d.*; *Cement Association of Canada n.d.*). The clean energy transition is a global transition, setting the conditions for success for Canada's economy, with major competitiveness risks and opportunity costs if Canada falls behind. (*Samson et al. 2021*).

For Canada to meet both the threat of accelerating climate change and the opportunity of the global clean energy transition, net zero is non-negotiable. Policymakers now face important choices about the pathway Canada takes to net zero, to navigate the clean energy transition while protecting affordability and seizing economic opportunities.

1. *British Columbia has committed to updating its target, but the legislation currently is set at 80 per cent emissions reduction below 2007 levels by 2050; the other provinces with legislated targets specify net zero by 2050.*

In most of the country, regulated utilities deliver the gas and electricity used to produce building heat and other critical energy services, such as hot water. These utilities are highly regulated in part because they provide essential services. Canada's energy regulators and the provincial policymakers that set the rules for those regulators will be central actors in the clean energy transition for building heat.

What looks like a promising option for a utility's bottom line may not always be in the best interest of ratepayers and the energy system overall, nor the most cost-effective path to net zero for the broader economy.

Energy utilities, however, are only beginning to map out what the clean energy transition means for their systems and customers. Some gas utilities are seeking to pivot to biomethane; others are starting to blend small amounts of hydrogen into their pipes.[2]

In some cases, both electricity and gas utilities are working together. For example, as electric heat pumps become increasingly efficient and cost-effective, utilities are exploring opportunities to pair them with gas heating backup to form hybrid systems that capture the benefits of heat pumps while keeping gas available for the very coldest days and nights of the year.

But what looks like a promising option for a utility's bottom line may not always be in the best interest of ratepayers and the energy system overall, nor the most cost-effective path to net zero for the broader economy. Furthermore, policymakers, utilities, and regulators may not yet fully understand or agree on the best pathways from the perspective of total system costs. Ambiguity and uncertainty can delay action, risking higher costs to reverse course later, or more pollution and missed climate targets.

This report seeks to advise policymakers—especially provincial and territorial governments—about how to facilitate the shift toward net zero buildings while protecting affordability, now and in the future.

2. ***FortisBC (BC)*** *has committed to 15 per cent biomethane blending in its networks by 2030, although it will achieve some of that percentage by purchasing credits from biomethane produced and used outside of British Columbia (Labbé 2023).* ***ATCO (AB)*** *is blending 5 per cent hydrogen in a small pilot project in Fort Saskatchewan (ATCO 2021).* ***Enbridge (ON)*** *is blending 2 per cent hydrogen in Markham, and has several biomethane projects, including blending biomethane from solid waste facilities in Toronto and from agricultural residues in Stratford, as well as a partnership to develop a new biomethane facility in Niagara Falls (Enbridge 2022).* ***Énergir (QC)*** *is aiming for 10 per cent biomethane by 2030; it is currently regulated to blend 1 per cent, a ratio scheduled to increase to 5 per cent in 2025. New gas customers in Quebec will be connected to 100 per cent biomethane (Sokic 2023).*

This report is structured as follows.

SECTION 1 brings clarity about least-cost pathways to net zero for buildings in Canada. It draws from new, original modelling analysis, literature review, and expert consultation. We identify some consistent patterns in what a cost-optimal pathway to net zero means for the buildings sector across the country, as well as important differences between provinces.

SECTION 2 assesses the extent to which space heating in Canada is currently on track to meeting net zero in a cost-effective way. We find that greenhouse gas emissions from the sector are still growing, and that investment in costly gas utility infrastructure continues apace despite a diminishing role for gas networks under net zero.

SECTION 3 assesses the sufficiency of existing provincial, territorial, and federal policies. Though more needs to be done, current climate policies—including carbon pricing, consumer incentives, and building codes—are influencing consumer choices. But to have an impact at the scale of electricity and gas utility systems, policy attention must also focus on the role utility regulators play in the clean energy transition.

SECTION 4 explores additional policy options, many of which aren't yet getting enough attention. Utility regulators have tools they can use now to align energy systems with net zero while protecting affordability for ratepayers. But stronger policy and clearer direction from provincial and territorial governments can enable utility regulators to do more to ensure prudent investments and to protect ratepayers over the long term. Without such clarity, continued investment in dead-end pathways risks compromising affordability for ratepayers, raising economy-wide costs, missing climate targets, or all of the above.

SECTION 5 presents a set of recommendations for policymakers to start putting Canada's buildings—and the gas and electricity networks that provide the energy to heat them—on track to cost-effectively meet the nation's climate commitments.

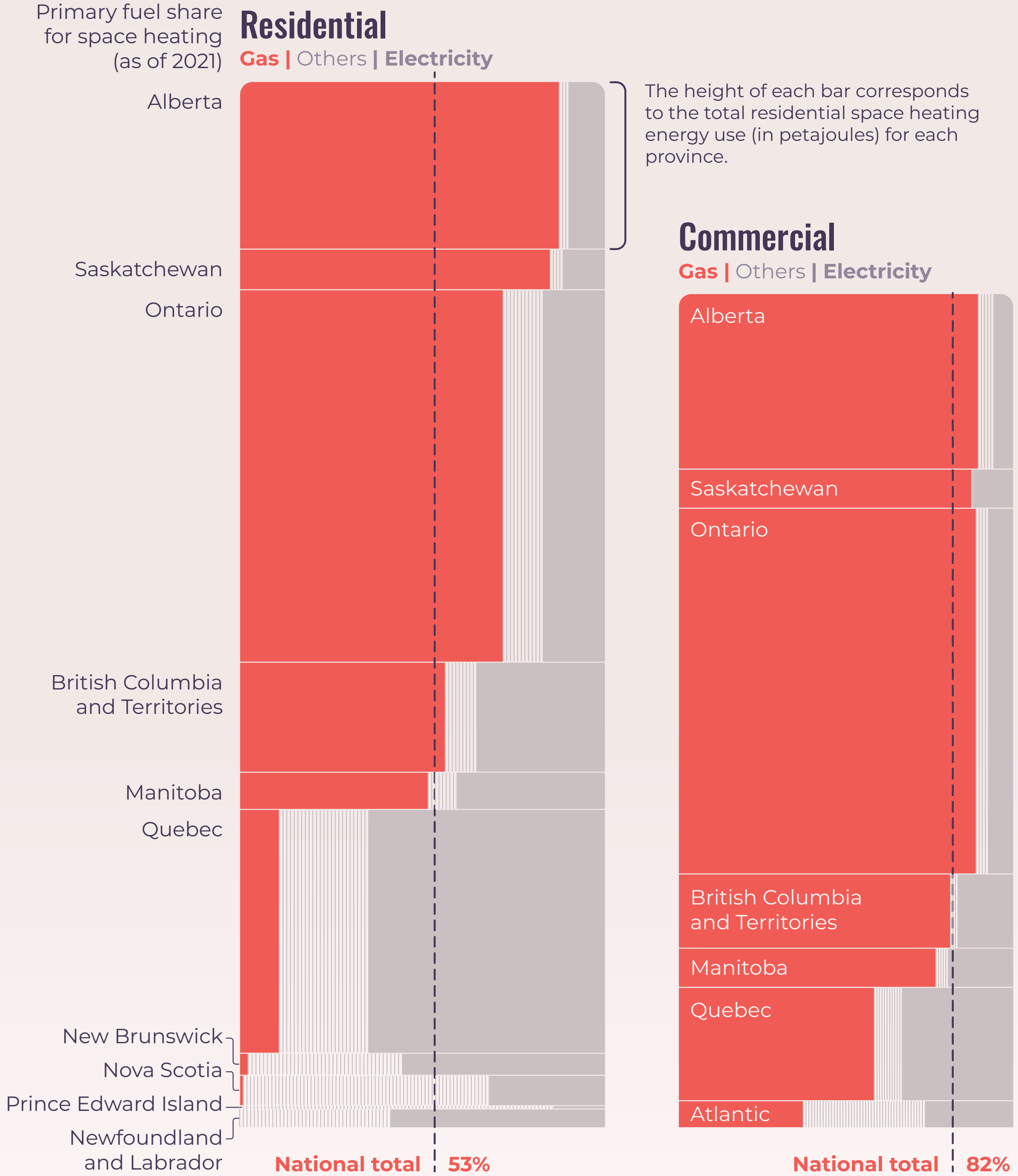
This report doesn't provide a complete policy roadmap for aligning building heat with net zero. The current fuel mix for space heating varies widely across the country (*see Figure A*). The cost-optimal pathway to net zero will be different in different places. Much of the policy work and transformative change in energy systems must be done province by province and even municipality by municipality, based on the specifics of each electricity and gas network.

And that work must start now. While a widespread shift in how Canadians heat their buildings will take place over decades, policymakers and regulators are making decisions today that will set the groundwork out to 2050 and beyond. Gas utility infrastructure, for example, is typically paid for by ratepayers over 40 to 50 years (or longer for some assets), so investment decisions have long-run consequences for consumer bills as well as potential liabilities if costly infrastructure goes unused or underused before it is paid off.

Protecting energy affordability throughout the energy transition requires that governments, utilities, and regulators think ahead and plan accordingly. By making forward-looking decisions today, policy makers can enable a successful and fair energy transition in which every home and business can access the clean, reliable heat they need.

Figure A

Gas furnaces and boilers currently provide space heating for more than half of Canada's buildings, but provinces vary significantly



SECTION 01

Net zero and **the future** of building heat

To explore the implications of a net-zero-aligned buildings sector for Canada's energy systems, we employed a techno-economic cost optimization model: the North American TIMES Energy Model (NATEM). This modelling analysis doesn't seek to prescribe a particular pathway to net zero, but instead identifies ways to reach net zero while minimizing costs to the whole system.

NATEM's cost optimization is economy-wide and covers a broad scope of costs, including energy commodity prices; consumer capital and operating costs; supply-side costs like infrastructure, operation, and maintenance; costs of energy efficiency investments; capacity expansion costs; and costs of early retirements. Minimizing overall costs helps to protect long-term affordability for households and businesses. This techno-economic cost optimization model is well-equipped to provide insights about consistent patterns in the cost-optimization findings in different regions, and across sensitivity analyses, and to investigate differences between building types and between regions.

The modelling analysis accounts for all energy demands in the buildings sector, including space heating and cooling, water heating, and cooking. We focus the analysis on space heating, rather than all energy usage in buildings, because space heating drives most of the energy demand in the buildings sector (58 per cent as of 2021), and because it underpins demand peaks—important considerations for ensuring energy system reliability. Due to data limitations and the particular opportunities and constraints of energy systems in the territories, the regionally specific analysis is focused on Canada's provinces.

WHY FOCUS ON PEAK DEMAND?

Peak demand is the period of time when electricity demand is at its highest. The height of the peak affects the size and cost of the electricity system. That's because it determines the amount of generation, transmission, and distribution capacity that must be available to meet the demand at its highest point. Peak demand can also be lowered by **load shifting** (moving demand from peak hours to non-peak hours), **peak shaving** (reducing demand at peak times) and overall demand reduction through improved energy efficiency. Most Canadian jurisdictions are winter peaking, which means that electricity demand is highest on the coldest days of the year, when the need for heating is highest. Currently, only Ontario is summer peaking, where demand for air conditioning on hot, humid days determines the time of highest electricity usage.

*In NATEM, the buildings sector includes **residential buildings** (single detached, single attached, apartments, and mobile homes) as well as **commercial buildings** such as offices, shops, and restaurants. Institutional buildings such as hospitals, schools, and universities are bundled with commercial buildings in this analysis. Residential buildings are more numerous—there were about 29 times more residential buildings than commercial and institutional buildings in 2020—but because commercial and institutional buildings are larger, space heating demand in the residential sector is estimated to be only 1.3 times greater than commercial and institutional demand in 2020.*

The modelling results help to clarify implications for the buildings sector of a cost-optimal path to achieving net zero economy-wide, as well as the potential trade-offs of pursuing alternative routes. We also tested the robustness of the modelling results with sensitivity analyses that were selected based on input from experts and industry stakeholders regarding key sources of uncertainty for future planning. (For additional detail on our modelling approach, including a list of sensitivity analyses, see Appendix 1.)

In this section, we describe and discuss the lead insights that our analysis surfaced. The major takeaways—that a cost-optimal pathway to net zero for Canada means increasing electrification, decreasing gas demand, and the need for investments in electricity capacity and energy efficiency—align with the findings of similar recent Canadian and international studies. (For a summary, see Appendix 2).

1.1 Overarching insights for Canada's energy systems

Overall, the model's cost optimization consistently shows a significant increase in the use of electricity for building heat, and a declining use of gas. This pattern is robust across the sensitivity analyses we ran, and consistent with other, similar net zero studies. We unpack these findings in more detail below.

Electrifying almost all building heat is the most cost-effective path to net zero

In all provinces and across all sensitivities, a cost-optimal pathway to net zero for the economy results in electricity becoming the dominant energy supply for building heat. Nationally, electricity's share of annual space heating energy demand rises from 21 per cent today to between 55 and 60 per cent by 2040 and between 78 and 91 per cent by 2050.

Electrification uptake varies by region, by sector, and by building type, but in almost all scenarios, getting to net zero means that electric technologies—led by heat pumps—heat most of Canada's residential buildings by 2050. Electric end-use technologies play a major role in commercial buildings as well—including in hybrid systems where heat pumps provide the bulk of heating needs. (For a description of end-use technologies for building heat, *see Table 1*).

In all regions, the model results show significant heat pump uptake in the residential buildings sector, including heat pumps deployed as part of a hybrid system (*see Figure B*). Heat pumps and electric resistance heating are the cost-optimal technologies for the system in the vast majority of homes by 2050. Widespread electrification of heat on a cost-optimal pathway occurs in part because heat pumps are so much more energy efficient than gas furnaces. When considering the broader economic impacts of the energy system, the alternative of using hydrogen or biomethane in buildings leaves less of those low-emission fuels available for other uses where they are highly needed, such as in heavy industry.

Table 1 Space heating technologies

HEAT PUMPS

Use electricity to move heat between locations. During the winter, a heat pump gathers heat from the outside air, ground, or a water source, and pumps it into a building, heating it. In the summer, the process works in reverse: heat pumps move heat from inside to outside, cooling a building. Heat pumps can work with ducts, similar to a forced-air furnace, or be ductless (mini-splits). Heat pumps are typically two to three times more efficient than electric-resistance heating.

Air-source heat pumps

Contain liquid refrigerant that absorbs heat from outdoor air. The refrigerant then boils to become a low-temperature vapour, which is in turn compressed, causing it to further heat up. The heat from the gas is then transferred into the indoor air, and the cycle repeats itself. The reverse cycle occurs in the summer, cooling the indoor air (*NRCan 2022*).

Cold-climate air-source heat pumps

Can operate at temperatures as low as –30° C.

Ground-source heat pumps

Circulate a liquid through underground or underwater piping, which absorbs heat. The liquid then passes through a heat exchanger, transferring its heat to the refrigerant in the heat pump. The heat pump can then transfer the heat to the indoor air. When cooling, the process works in reverse (*Efficiency Manitoba 2021*).

ELECTRIC RESISTANCE HEATING SYSTEMS

Electric furnaces

Use fans to pull air across electrically heated elements and then distribute it through a building via ductwork.

Electric boilers

Pass electricity through a resistive conductor, which heats water. A circulating pump moves the heated water around the home through radiators or underfloor heating pipes, distributing heat.

Table 1 (continued)

Electric baseboards

Operate as individually controlled units around a building. They generate heat from an element, which then radiates into the room.

HYBRID HEATING SYSTEMS

Combine the installation of an electric heat pump with a gas furnace. The heat pump provides heating and cooling most of the time, but the furnace is available at very low temperatures when heat pumps can lose efficiency and effectiveness.

CONVENTIONAL FURNACES AND BOILERS

Furnaces

Burn gas, oil, or propane to generate heat, which passes through a heat exchanger. Fans blow air across the heat exchangers, then circulate the heated air through the building via ductwork.

Boilers

Burn gas, oil, or propane to heat water. The equipment then distributes hot water or steam through pipes to radiators.

All gas-fired furnaces and boilers can also burn biomethane without modification.

HYDROGEN FURNACES AND BOILERS

Similar to their conventional gas counterparts, but instead burn hydrogen. Boilers and furnaces that use 100 per cent hydrogen are not yet commercially available.

THERMAL ENERGY NETWORKS

Generate or recover, then distribute heat through a connected pipe network, instead of distributing gas. The heat can be generated directly with fossil fuels or with renewable sources such as bioenergy, solar thermal, geothermal, or air-source, water-source, or ground-source heat pumps. Thermal energy networks can also be a component of cogeneration (combined heat and power) systems or systems that make use of waste heat, for example from wastewater or industrial operations. Some thermal energy networks can also provide space cooling by circulating chilled water.

BIOMASS STOVES

Use biomass fuels (for example, wood pellets) for heating.

Figure B

On a cost-optimal path to net zero, electricity overwhelmingly powers space heating by 2050, even in provinces that rely heavily on gas today

Primary space heating mix in the **residential sector**, % market share by technology

Today, 34% of HOMES in Canada heat with electricity, mostly baseboards.

To meet net zero, nearly all home heating in 2050 is entirely or mostly powered by electricity, including heat pumps backed up by gas in a hybrid system.

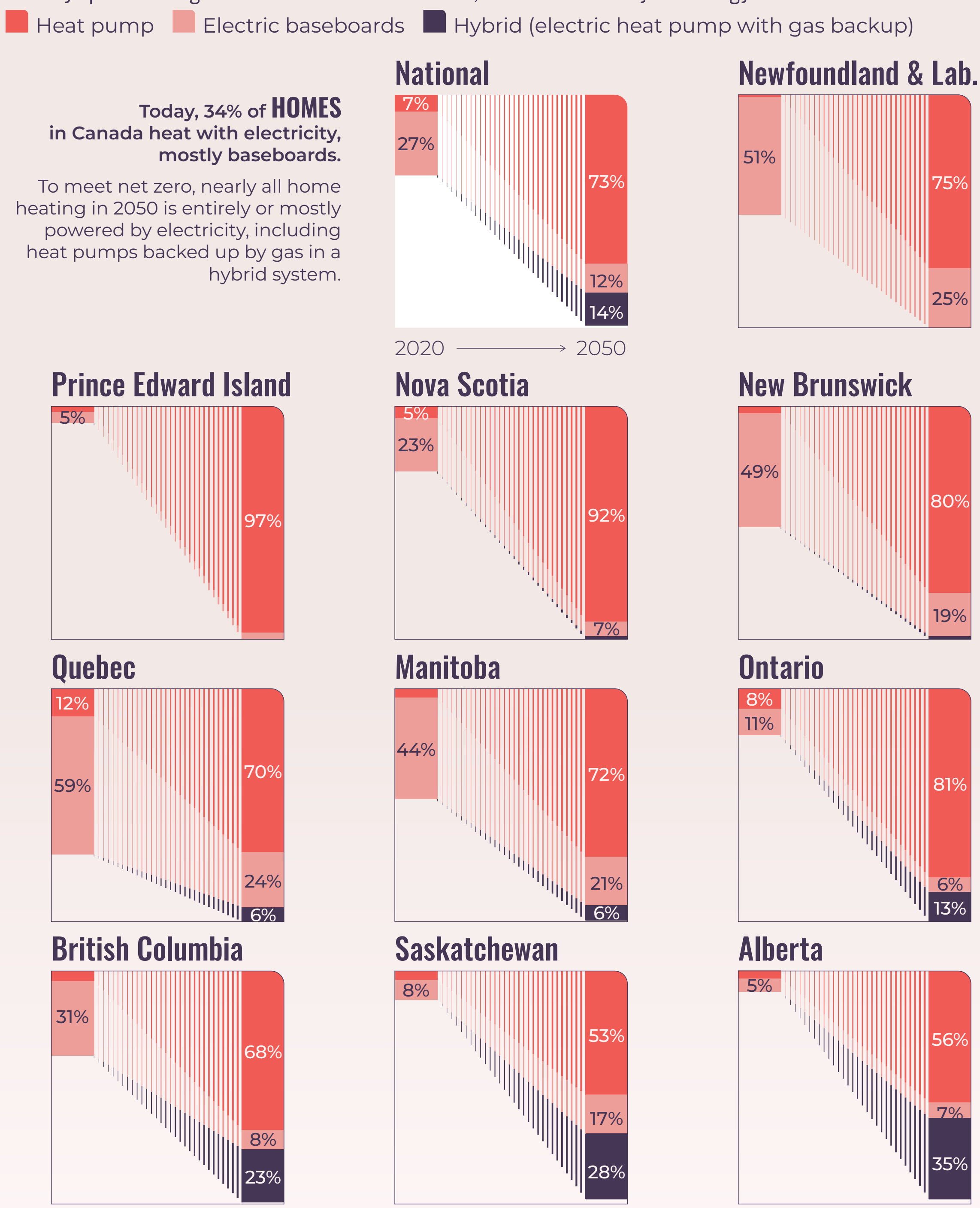


Figure B (continued)

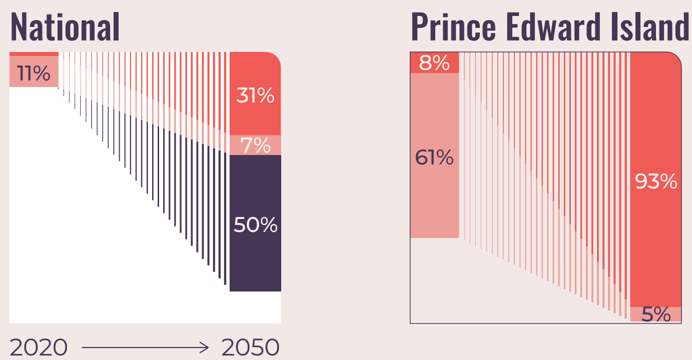
On a cost-optimal path to net zero, electricity overwhelmingly powers space heating by 2050, even in provinces that rely heavily on gas today

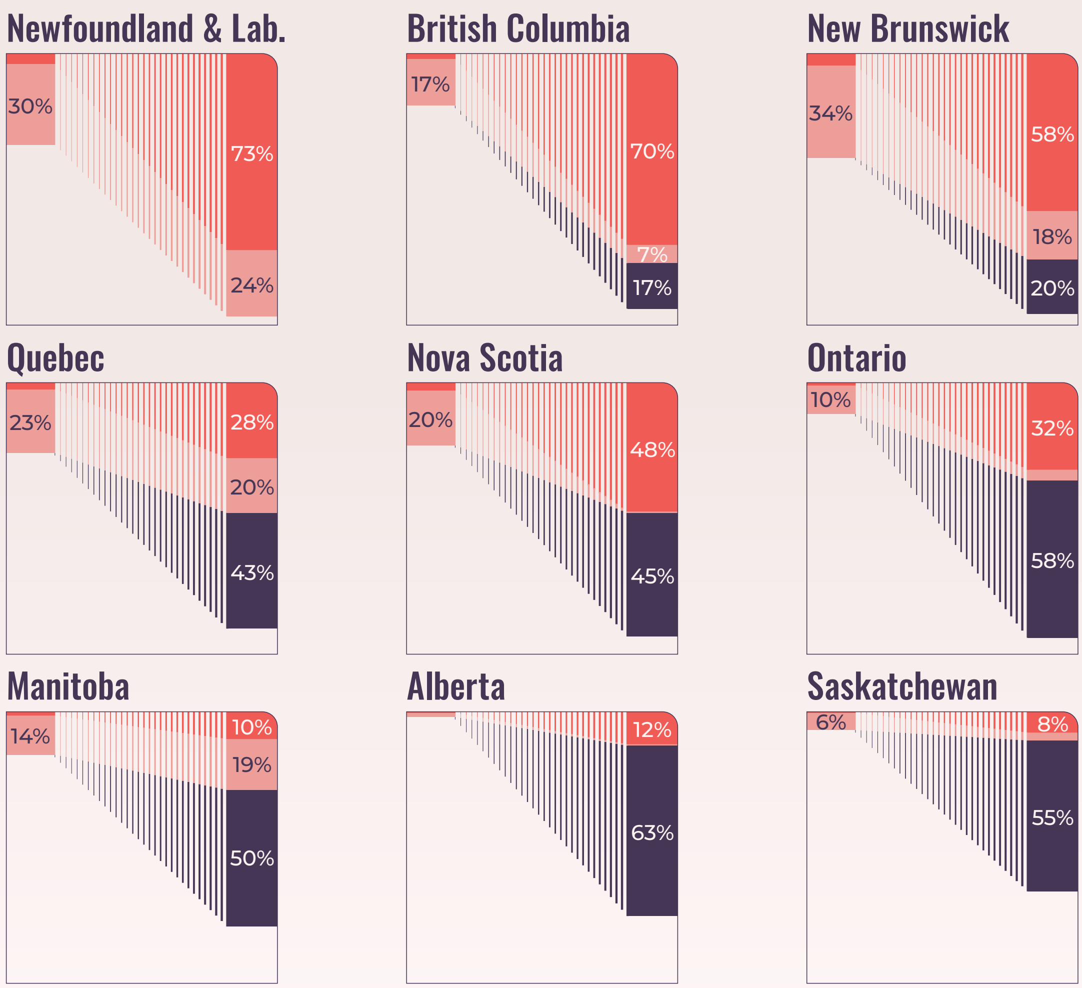
Primary space heating mix in the **commercial and institutional sector**, % market share by technology

Heat pump | Electric baseboards, furnaces, and boilers | Hybrid (electric heat pump with gas backup)

Today, 13% of COMMERCIAL and INSTITUTIONAL SPACES in Canada heat with electricity.

To meet net zero, 88% of commercial and institutional heating in 2050 is entirely or mostly powered by electricity, including heat pumps backed up by gas in a hybrid system.





Electric end-use technologies gain significant market share in residential space heating by 2050, even in provinces that mostly heat with gas now, such as Alberta, Saskatchewan, and Manitoba. Under the cost-optimal pathway, some of these regions deploy hybrid heating systems that pair electric heat pumps with a back-up gas furnace. Alberta sees the highest uptake of hybrid systems at 35 per cent of market share in 2050, compared to an average of 14 per cent across Canada. We discuss hybrid systems in greater detail in *Section 1.2*.

Provinces with little to no existing gas infrastructure, including Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador, see all-electric end-use technologies (heat pumps and electric resistance heating) grow to make up nearly all of their residential market share by 2050.

The electrification of space heating in commercial and institutional buildings is more varied across provinces compared to the residential sector. Commercial and institutional buildings use a greater range of technologies, such as geothermal heat pumps, thermal energy networks, and hydrogen boilers, but only in some provinces. They also see a higher uptake of hybrid heating systems.

This finding of high rates of electrification is robust across sensitivity analyses. Under a sensitivity analysis that tests a lower range of efficiency improvements for heat pumps, the results show slightly lower overall electrification levels, but electricity still meets 78 per cent of annual space heating energy demand by 2050. Even under sensitivity analyses that combine lower costs and greater availability of low-emission gases with higher costs for electric end-use technologies, a widespread shift to electric building heat still tends to be more cost-effective than significant use of low-emission gases in the buildings sector.

Similarly, sensitivity analyses testing the possibility of higher biomethane feedstock availability and lower costs of biomethane production do not decrease the proportion of building heat provided by electricity.

As for hydrogen, we find that even assuming lower supply and end-use technology costs and setting blending rates to 20 per cent does not materially impact the rate of electrification of building heat. Adjusting assumptions on the costs of end-use hydrogen technologies to 50 per cent lower than baseline assumptions only shows an effect in the commercial sector: a 12 per cent increase in the market share of hydrogen technologies, and a corresponding decline in the market share of hybrid systems. The market share of full-electric technologies is unaffected. Reducing the costs of production by 30 per cent from the baseline assumption also shows no impact on the share of hydrogen technology uptake.

This persistent finding of electrification as the cost-optimal pathway for buildings comes in part because, from a whole-economy perspective, it is more cost-effective for scarce low-emission gases to go toward decarbonizing other sectors. Sectors such as heavy industry and hydrogen production consistently consume the majority of biomethane in the model.

It is more cost-effective for scarce low-emission gases to go toward decarbonizing other sectors.

This finding on the importance of electrification is broadly consistent with other major Canadian and global studies that have investigated the same topic (*IEA 2021*; *Mahone et al. 2018*; *Williams et al. 2021*; *Langevin et al. 2023*; *European Climate Foundation and European Alliance to Save Energy (EU-ASE) 2022*; *Guidehouse 2022*). For example, in EPRI's Canadian National Electrification Assessment's net zero scenario, electric heating share increased in both residential and commercial buildings to 76 per cent and 73 per cent respectively by 2050 (*EPRI 2021*). Similarly, the Trottier Energy Institute's Canadian Energy Outlook reported that across their net zero scenarios, electricity would account for more than 95 per cent of total consumption in the buildings sector by 2050 (*Langlois-Bertrand et al, 2021*).

In all provinces, gas use in buildings declines steeply as Canada decarbonizes

On a cost-optimal path to net zero, total gas consumption in buildings falls in every province, including in the major gas-consuming provinces of Alberta, Ontario, Saskatchewan, British Columbia, and Manitoba (*see Figure C*).

As overall gas consumption declines, the use of biomethane and hydrogen in the buildings sector increases, but only slightly. Because electrification is so much more cost-competitive and because there is competition for their use from other sectors, even by 2050, these fuels would replace only a small fraction of current gas demand (*see Figure D*). Across all sensitivity analyses, by 2050, the extent of hydrogen and biomethane demand in the buildings sector overall (including space heating, water heating, and cooking applications) only makes up between 5.1 and 12.7 per cent of 2020's total gas demand. These modelling results illustrate the very limited role of any kind of gas in the buildings sector in 2050 on a cost-optimal pathway to net zero.

Figure C

On the path to net zero, buildings sector gas use declines in all provinces

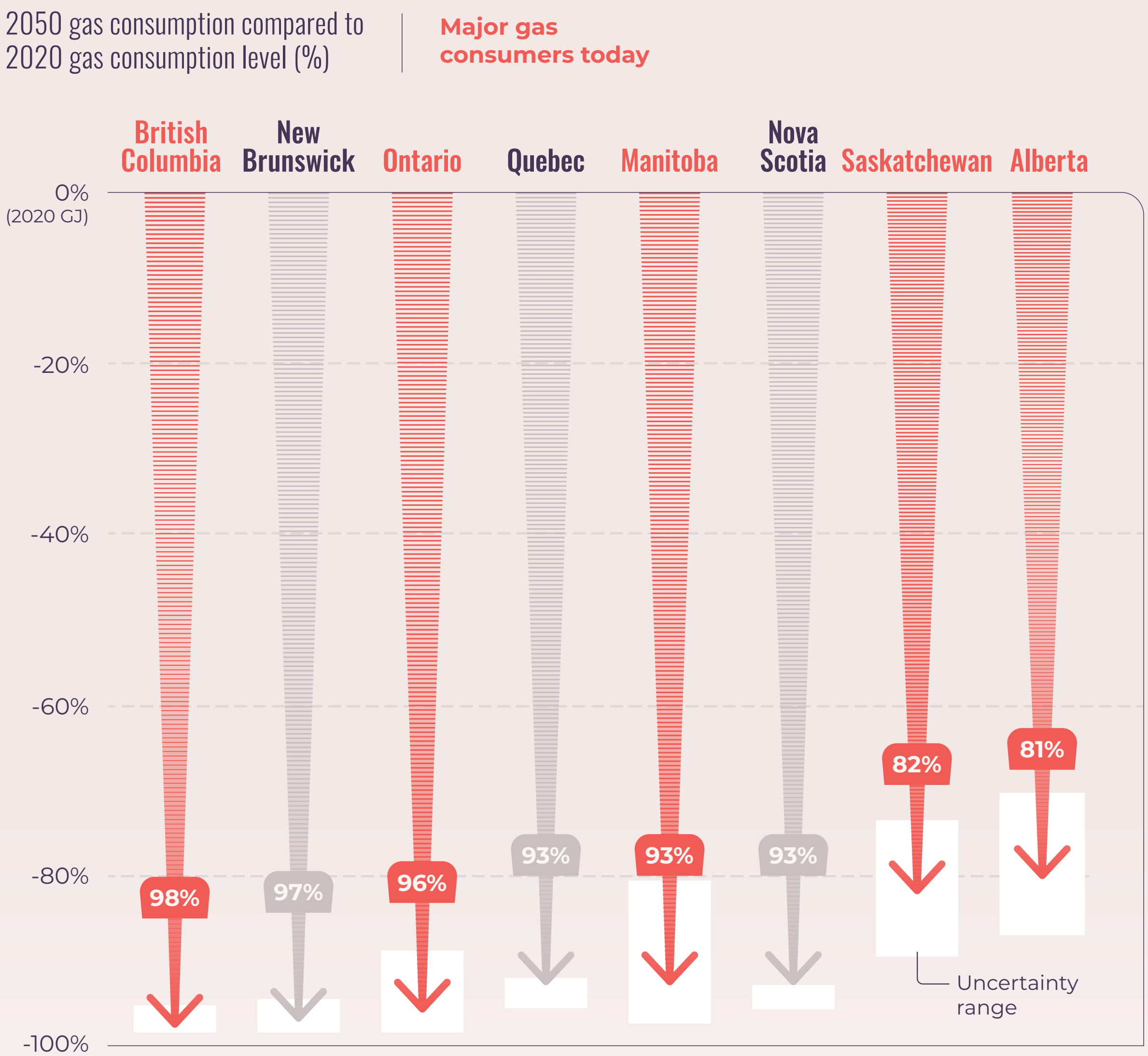
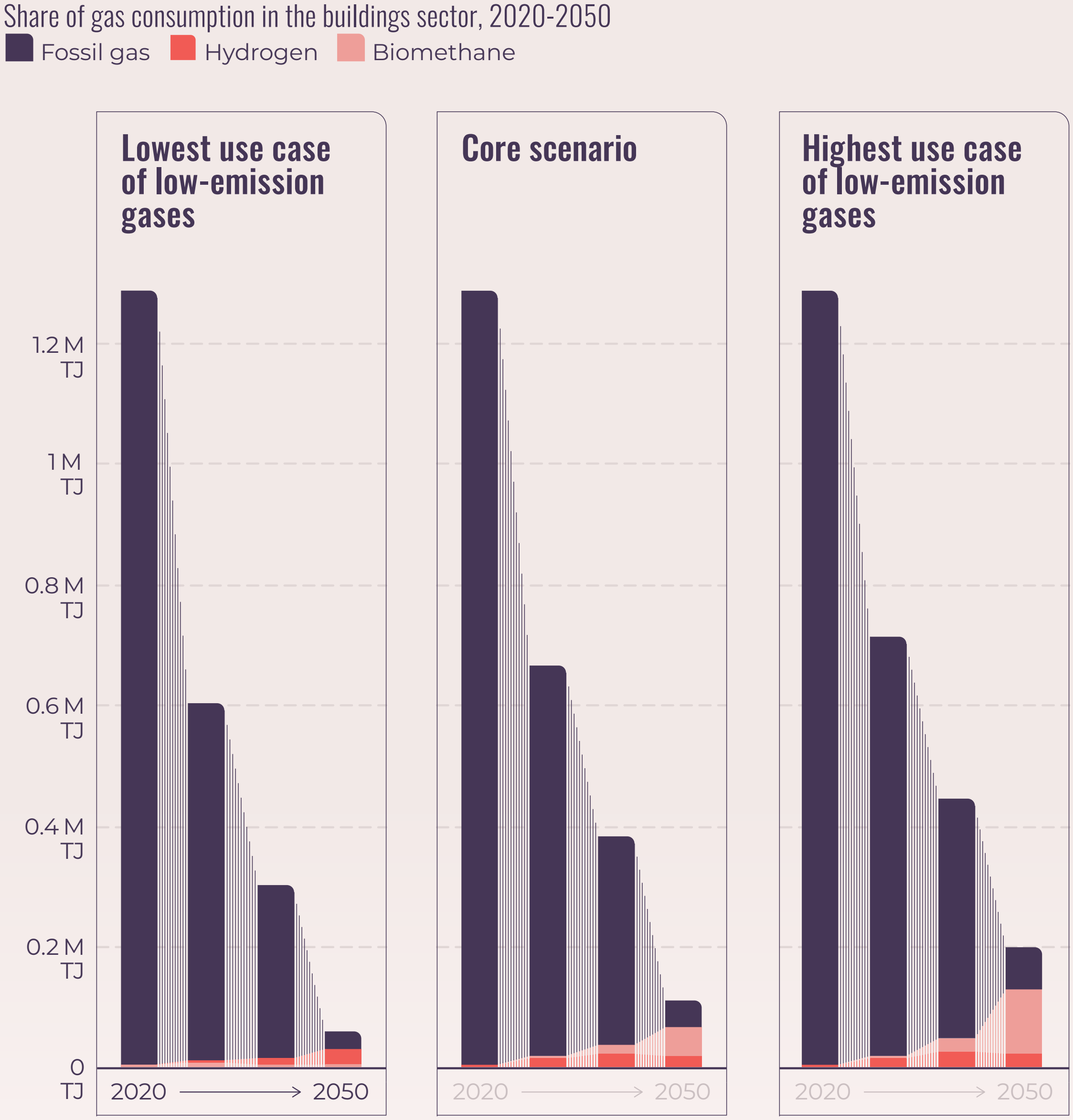


Figure D

On a cost-optimal pathway, biomethane and hydrogen only replace a small fraction of today's gas use in buildings



HYDROGEN AND BIOMETHANE

Hydrogen and **biomethane** are two alternative gases that could be used for building heat. **Hydrogen** can be produced with fossil fuels or electricity, with lower greenhouse gas intensity if it is coupled with carbon capture technology or produced using renewable electricity (*IEA 2023b*). Hydrogen can be used in fuel cells, or burned to produce energy. It is not, however, a full substitute for methane gas—at any pressure, the volumetric energy density of hydrogen is about one third that of methane. To date, Canadian gas utilities have only tested low-percentage blends of hydrogen in existing gas infrastructure.

Biomethane, also called renewable natural gas or RNG, is a form of biogas that is produced from anaerobic digestion or direct gasification of organic feedstocks such as wood and crop residues, manure, corn silage, or pulp mill sludge. Once it is refined, biomethane can be injected directly into existing gas distribution infrastructure and burned in any existing gas space heating equipment.

The decline in gas use on a cost-optimal pathway to net zero is consistent across various sensitivities, including those that test lower cost and higher availability assumptions for low-emission gases. Under low-cost assumptions for hydrogen, more hydrogen furnaces and boilers are deployed in commercial buildings in Alberta, Saskatchewan, and Manitoba. However, total gas consumption from the buildings sector in these provinces still drops by 70 per cent in Alberta, 73 per cent in Saskatchewan, and 80 per cent in Manitoba. Under a sensitivity analysis that tests higher assumptions for the availability of biomethane feedstocks, the results show similar levels of biomethane use in buildings; the additional feedstocks are more cost-optimally used elsewhere.

This finding of declining gas demand for space heating is consistent with other net zero studies. For example, the Canadian Energy Outlook report shows that gas use in the buildings sector falls in all net zero scenarios; gas consumption is projected to decline and be only 4 to 8 per cent of 2016 demand by 2050 (*Langlois-Bertrand et al. 2021*). Studies in other countries have reached similar conclusions; for example, Guidehouse's Decarbonisation Pathways for the European Building Sector shows that, in a highly electrified pathway, gas is no longer used in buildings by 2050, and even in a pathway that deploys more hybrid systems and low-emission gases, gas demand still declines by 70 per cent by 2050 (*Guidehouse 2022*).

The levels of gas decline estimated by the NATEM model may even be an underestimate, due to limitations in how it captures the potential dynamics of gas-demand decline. The model can identify where it is most cost-effective to switch from gas to electricity to meet emissions targets, but it does not account for how falling gas demand could raise costs for remaining customers—leading to further customer defection. This can create a negative feedback loop, in which customer defection from the gas network increases costs for remaining customers as a shrinking customer base must pay for gas network maintenance. Those higher costs for remaining customers drive additional defections, and so on.[3]

While the model optimizes for system-wide costs (how much it costs overall), it does not optimize for potential distributional concerns (who pays those costs). Higher costs for remaining customers represents not only a potential accelerant of gas demand decline. It also represents an important equity challenge for policymakers, which we discuss further in *Section 3*.

3. *A recent study from the Brattle Group identified this dynamic as a major energy transition risk for gas utilities in the United States. They find that by 2040, given existing policies, electricity could replace 60 per cent of the heating demand currently being served by the gas sector in New York, increasing gas bills for remaining customers by 71 per cent (Graves et al. 2021). In the United Kingdom, their regulator noted a similar concern about the potential for spiralling network charges, with residual asset value (currently C$45 billion) paid for by fewer and fewer customers over time (Ofgem 2023). In February 2024, the energy regulator in France announced that gas rates will increase by 5.5 to 10.4 per cent in July 2024 to cover fixed costs amid declining gas consumption (franceinfo 2024).*

1.2 Implications for the electricity system

The widespread electrification of building heat—alongside electrification of other energy end uses on a pathway to net zero—has major implications for electricity system investments.

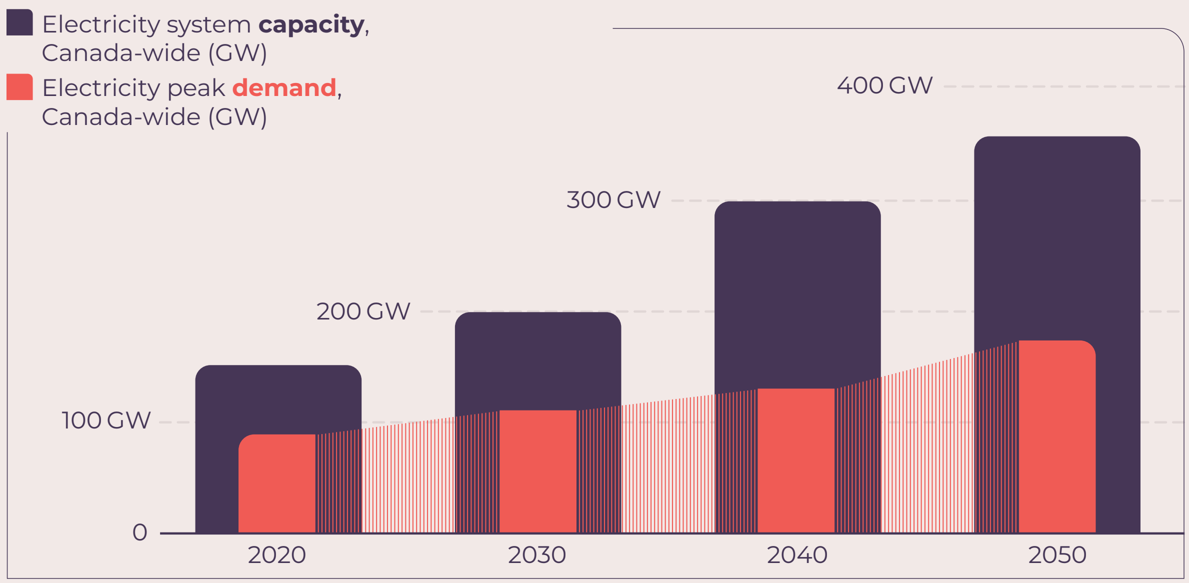
> A significant investment in electricity system capacity, reliability, and resilience will be required to reach net zero by mid-century

Increased electricity demand from all sectors necessitates significant additional electricity generation capacity. To meet net zero on the cost-optimal pathway, the model projects an electricity capacity build-out to a national average of 2.6 to 2.9 times the amount in place today, across all of the sensitivity analyses (*see Figure E*). This expansion of electricity systems is broadly consistent with other net zero modelling studies. Our previous research found that installed electricity capacity must grow between 2.2 and 3.4 times by 2050, compared with 2020, in order to reach net zero (*Lee et al. 2022*).

This scale of electricity capacity expansion is the result of higher demand from electrifying activities across the whole economy, not just buildings, but also from the addition of more intermittent renewables to the generation mix. Peak electricity demand from the buildings sector rises. But as other sectors such as transportation and industry also electrify and new electrified technologies such as direct air capture emerge, the percentage of total peak demand due to usage in the buildings sector declines. In 2020, electricity use in buildings drove 69 per cent of peak demand nationally, whereas our modelling finds that in 2050, when most of the buildings sector is electrified, buildings would only be responsible for 48 per cent of winter peak electricity load.

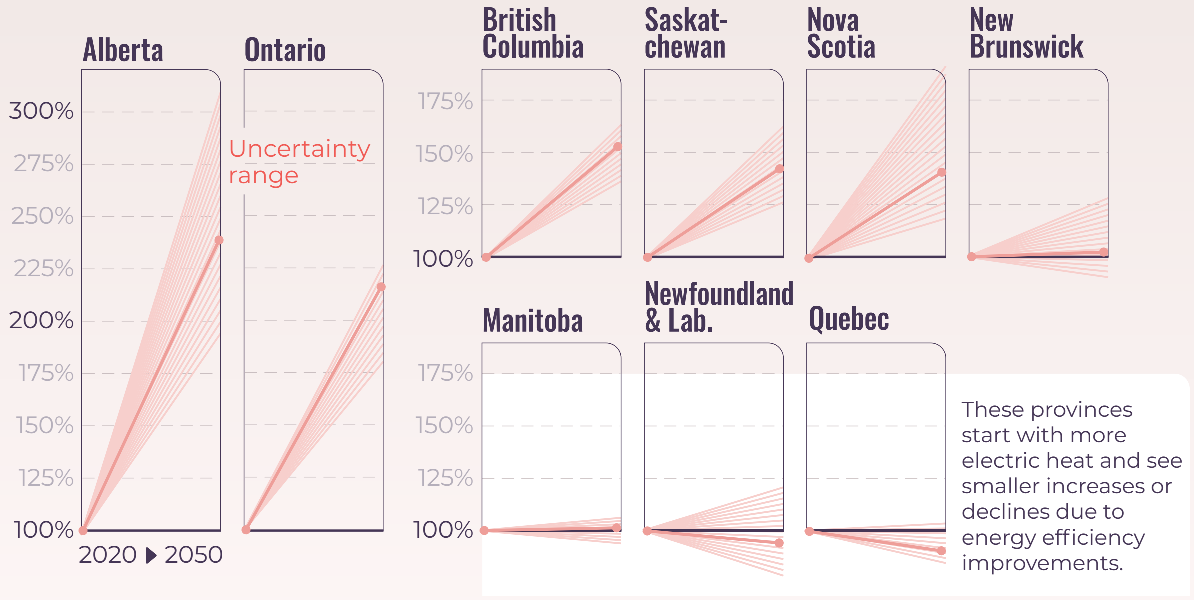
Figure E

Overall electricity capacity needs to increase. Electrification in all sectors, not only buildings, drives growth in peak demand



Peak demand from the buildings sector will climb in some provinces and decline in others

Peak demand change compared to 2020 (%)



Even though electricity demand increases, total energy demand decreases dramatically. On a cost-optimal pathway to net zero, from 2020 to 2050, the total square footage of buildings increases as the population and economy grows. But due to significant improvements in energy efficiency over time, total energy demand from the buildings sector declines on a cost-optimal path to net zero.

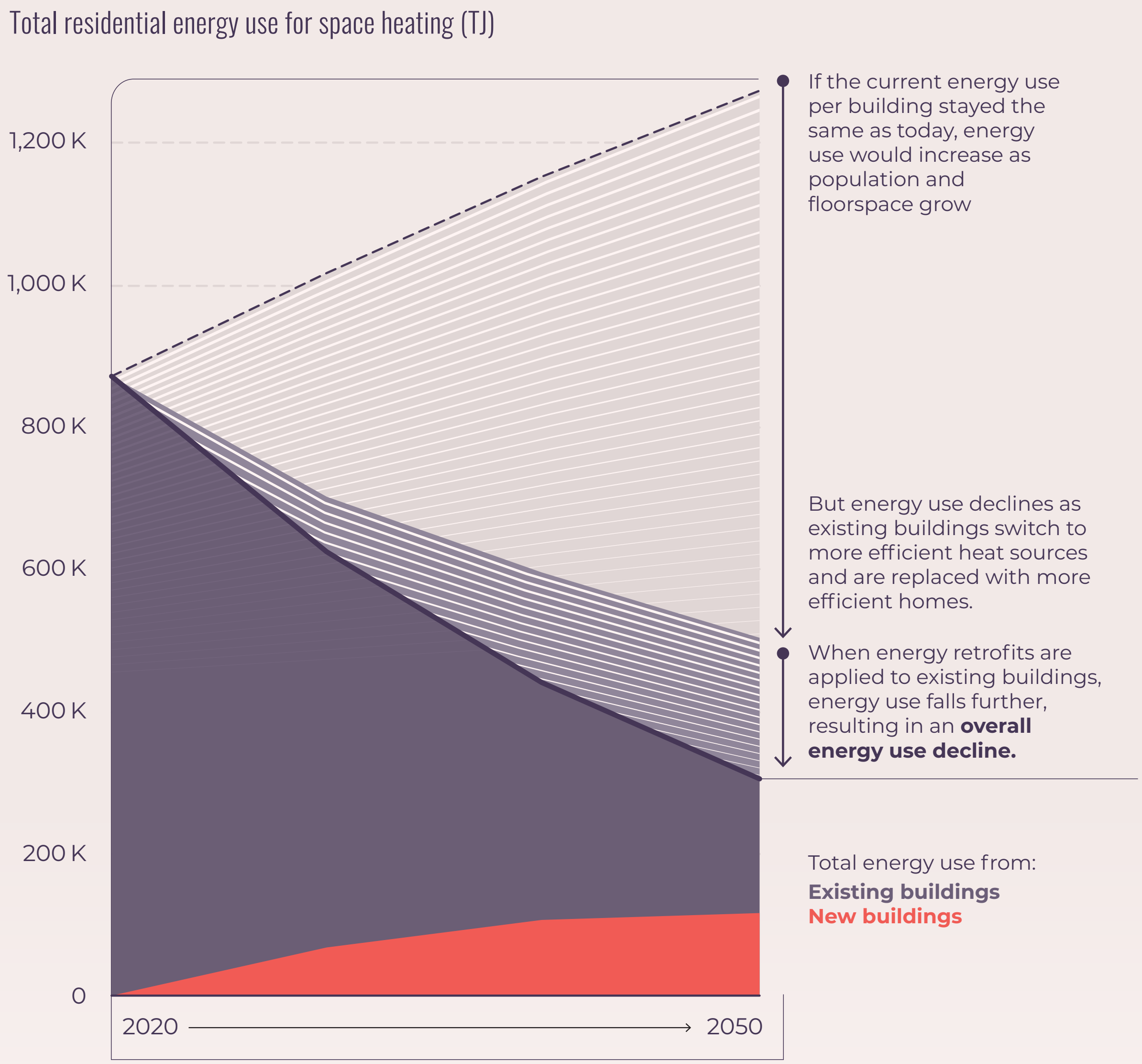
Historically, total energy demand for space heating residential buildings in Canada has remained fairly flat, even as floorspace increases, as existing buildings are retrofitted and newer, more efficient buildings replace older buildings (*NRCan n.d.*). In our modelling results, efficiency improvements result in lower total energy demand from the buildings sector in 2050 compared to 2020 (*see Figure F*). Fuel switching to heat pumps is responsible for much of those energy savings, as heat pumps are typically 1.4 to 3.7 times more efficient than gas furnaces at converting energy into useful heat (*Ferguson and Sager 2022*). Energy efficiency retrofits of existing buildings and the replacement of older buildings with more efficient new buildings drive further energy savings. Altogether, total space heating energy demand from the buildings sector falls by more than half between 2020 and 2050.

In Quebec, New Brunswick, and Newfoundland and Labrador, which currently rely more on electric baseboards for heat, the switch from less efficient electric resistance heating to heat pumps results in sufficient energy savings to decrease overall electricity demand from building heat. For example, in Newfoundland and Labrador, which currently relies on electric baseboards for 41 per cent of its residential and commercial heating, efficiency improvements are sufficient to cause electricity demand from space heating in buildings to fall 31 per cent between 2020 and 2050 as customers switch to heat pumps and benefit from better building envelopes. The energy savings more than offset other factors, such as population growth, which push up demand.

In provinces that currently rely more heavily on gas heat, the widespread uptake of heat pumps, alongside other ongoing electrification (for example, of personal transport), does significantly increase electricity demand, necessitating electricity system investments to meet winter peak demand in ways that maintain reliability. Moreover, increasing Canada's reliance on electricity in a changing climate—with more frequent and more intense threats to electricity infrastructure from extreme weather—heightens the imperative to invest in system resilience.

Figure F

Buildings' total energy use declines on the path to net zero due to improving efficiency



Investments to reliably meet peak winter electricity demand also yield benefits for summer peaks. The electricity system supports peak cooling demand in summer (when gas systems play a very small role), and cooling demand has increased over the past century. Some provinces, such as Ontario, are already summer-peaking systems, while some others may see the gap between winter and summer demand narrow or even have summer peaks surpass their winter peaks as the climate warms (*CER 2021*; *Mertz 2021*; *Government of British Columbia 2015*).

Managing demand peaks is crucial to any cost-optimal net zero pathway

Energy efficiency measures can reduce energy demand in general, including at peak times. Energy retrofits and switching to more efficient technologies like heat pumps require significant effort and investment. But the extent of their deployment on a cost-optimal pathway speaks to how cost-effective energy efficiency is at minimizing total system costs.

Lower levels of energy efficiency and fewer building retrofits would require more electricity generation capacity, resulting in higher overall costs. A sensitivity analysis in which we assume 80 per cent fewer energy retrofits and reduced efficiency of heat pumps results in higher winter and summer demand peaks. This, in turn, requires more installed electricity capacity: 5 per cent more in 2040 and 3 per cent more in 2050. These higher peaks also translate into higher total electricity system costs—up 12 per cent in 2040 and up 9 per cent in 2050.

In addition to broader energy efficiency measures, measures to specifically reduce electricity demand at peak times (known as peak shaving) and shift demand to non-peak times (load shifting) can mitigate costs associated with demand peaks. Many tools are available to do so, and utilities can and should deploy them as a portfolio, rather than in isolation (*See Figure G*).

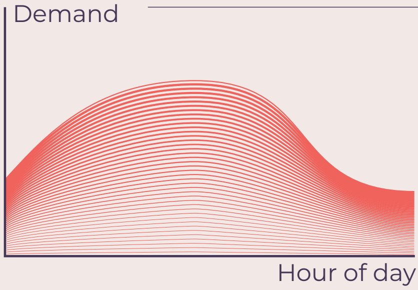
The range of potential peak management tools outlined in *Table 2* is broader than the energy efficiency retrofits we model. Distributed storage technologies, for instance—including thermal storage and batteries at multiple scales, from the utility level down to neighbourhoods, electric vehicle fleets, and in buildings—are multiplying the options available to shift demand to non-peak hours while storing electricity to meet demand spikes. These options are relatively new, but experience with them is growing. For example, a Vermont utility is providing utility-owned batteries to customers to bolster grid resilience and promote energy decentralization (*DiGangi 2023*). As part of a new pilot program, Nova Scotia Power is offering customers home battery systems, which can be used by homeowners in case of outages, and could be deployed by the utility to feed energy back to the grid in times of peak demand (*Nova Scotia Power n.d.*).

NATEM and similar models do not yet capture most of these newer measures and technologies. It is therefore difficult to characterize their potential contributions, although evidence from other studies suggests that they could be considerable—both on limiting costs and improving system reliability (*Nadel 2017*; *EIA 2019*; *Gattaciecca et al. 2020*; *Specian 2021*; *Bronski et al. 2015*; *Fitzgerald et al. 2015*; *Martin and Brehm 2023*; *Srivastav et al. 2024*). For example, in 2015, the ACEEE looked at potential demand response savings from 28 utilities, finding that on average these energy savings could be 10 per cent or more of system peak (*Nadel 2017*). A study from the Rocky Mountain Institute found that residential demand flexibility measures could result in $13 billion per year of avoided grid costs in the United States, and reduce total peak demand by 8 per cent (*Bronski et al. 2015*).

Demand-side measures, including deep retrofits and newer types of demand-side management and response, reduce costs for the entire system, not just the customers who implement them. Some regulators and utilities include energy efficiency investments as a resource for meeting energy needs, and evaluate the relative cost-effectiveness of those investments compared to supply-side alternatives. Such demand-management tools can play a key role in meeting energy needs while minimizing the costs associated with achieving economy-wide electrification.

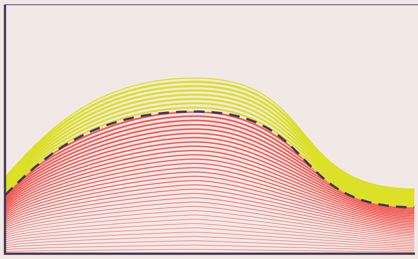
Figure G

Various tools can help manage electricity demand peaks and lower system-wide costs



Baseline demand

Baseline consumer demand for electricity has peaks and valleys depending on the time of year and the time of day

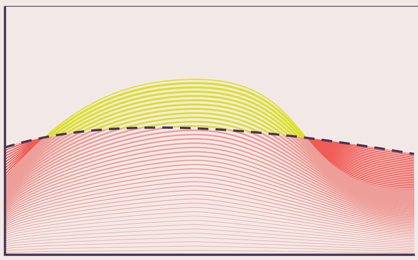


Energy efficiency

Lowers overall energy demand, including peak demand

Building envelope improvements

Higher efficiency appliances



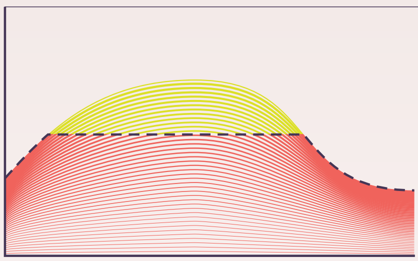
Load shifting

Moves electricity demand to off-peak times

Smart technologies and energy management systems

Distributed energy storage

Off-peak incentive rates



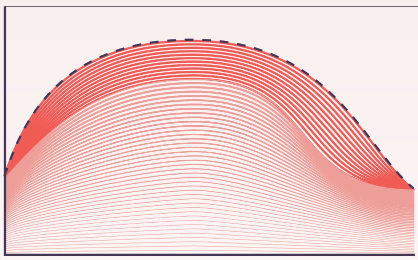
Peak shaving

Lowers electricity demand at peak times

Interruptible supply rates for large loads

Consumer peak reduction incentives

Smart technologies and appliances



Supply-side flexibility

Can dispatch clean electricity when demand is unusually high (e.g., cold snap, heat wave)

Grid interties for trade

Utility-scale storage

1.3 Implications for the gas system

The flipside of growing electricity demand and growing investments in the electricity system in the clean energy transition is falling gas demand. Gas demand from buildings declines on a cost-optimal pathway even with the availability of options such as biomethane, hydrogen, and hybrid heating systems. We consider implications for those decarbonization strategies below, as well as what declining gas demand means for the gas network.

Building heat is not a cost-effective use of low-emission gases

Biomethane and hydrogen are relatively scarce and expensive, and supplies are projected to remain limited.[4] Yet some sectors, such as heavy industry, will struggle to decarbonize without using them. In contrast, electricity is a simple and cost-effective option for building heating—meaning that it is more cost-effective for the economy as a whole to reserve their use for sectors where they provide the best value.

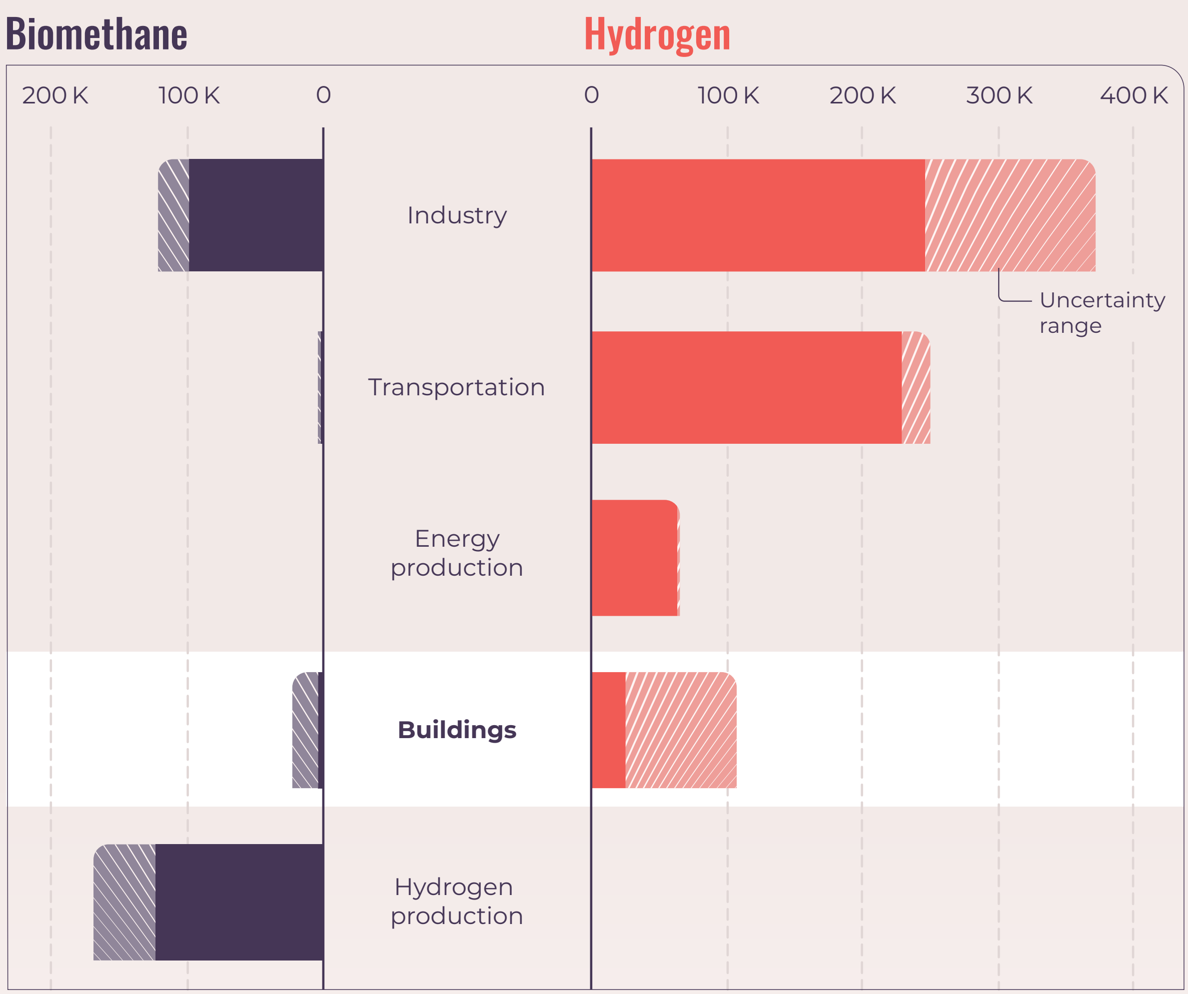
When cost-optimizing for the entire economy, the modelling results show biomethane and hydrogen are primarily used in other sectors, not for building heat. By 2050, Canada's buildings sector is using only 6 per cent of available hydrogen and 6 per cent of available biomethane. The rest is taken up in the industry, transportation, and energy production sectors (*see Figure H*).

4. *Hydrogen production cost assumptions in the NATEM model are derived from a range of studies, including IEA's* ***The Future of Hydrogen*** *report, Element Energy* ***Hydrogen Supply Chain Evidence Base, Data and Assumptions****, and various NREL datasets. Biomethane production cost assumptions were derived from IEA's* ***Outlook for biogas and biomethane report****, other literature, and consultations with stakeholder groups in this space.*

Figure H

On a cost-optimal path to net zero, the buildings sector only accounts for a small amount of low-carbon gas use

Low-emission gas use by sector in 2050 (TJ)



Feedstock constraints are an important limiting factor for biomethane production. Recent studies estimate that, given current feedstock availability and existing production technologies, Canada could feasibly produce between 90 and 218 petajoules of biomethane per year (*Abboud et al. 2010*; *Kelleher Environmental 2013*; *Stephen et al. 2020*). This is equivalent to only 2 to 5 per cent of Canada's total 2021 gas demand (*CER 2023*).

Early-stage technologies that produce synthetic gas from solid biomass could enable Canada to access forestry industry residues as feedstock; doing so would increase biomethane production potential by 150 petajoules, or 4 per cent of gas demand as of 2020. If active forest management techniques such as thinning are applied on Crown timberlands, this estimate could increase by several hundred petajoules (*Stephen et al. 2020*).

Even if the higher ranges of biomethane availability forecasts are realized, supplies available to the buildings sector will likely still be limited due to competing uses, such as heavy industry (*see Figure F*). Indeed, in the sensitivity analyses, tripling available biomethane feedstocks and reducing the cost of biomethane production by 30 per cent does not lead to an increased uptake of biomethane in the buildings sector. Instead, other sectors that are more difficult or more expensive to electrify use more biomethane.

The modelling results also suggest that biomethane feedstocks may be more efficiently used as direct fuel sources rather than converted into biomethane. When available biomethane feedstocks are tripled in the model, some of the additional feedstock is used to meet end-use energy demands directly; in particular, the buildings sector shows more than a fivefold increase in wood and wood-pellet fuel use in this scenario.

Global supply constraints make it unlikely that international trade will significantly increase Canada's domestic biomethane supply. The International Energy Agency estimates that if all current sustainable feedstocks for biomethane were used, they could serve just 20 per cent of current global gas demand (*IEA 2020*).

The use of hydrogen for building heat is constrained by cost and competition with other sectors.

In our modelling results, the vast majority of hydrogen is more cost-optimally used in sectors other than the buildings sector, such as heavy industry. On a cost-optimal pathway, we only see hydrogen boilers deployed in commercial buildings in Alberta, Manitoba, and Saskatchewan, at market shares of 15 per cent, 6 per cent, and 22 per cent, respectively. When we assume a halving of the costs of hydrogen-compatible end-use technologies in a sensitivity analysis, we find a notable increase in their deployment in Alberta, Manitoba, and Saskatchewan, to 53 per cent, 42 per cent, and 57 per cent of the commercial market share, respectively. However, even with low-cost assumptions, hydrogen end-use technologies are not deployed in residential buildings anywhere.

Generally in the modelling results, we see some uptake in the use of biomethane and hydrogen in the buildings sector along a cost-optimal pathway to net zero, but nowhere near enough to replace the sector's current gas consumption.

Hybrid systems play a role in some contexts, but use very little gas by 2050

Hybrid space heating systems that pair heat pumps with gas furnaces—predominantly replacing stand-alone furnaces in existing buildings—grow in market share along a cost-optimal pathway to net zero, particularly in some contexts.

Targeted use of hybrid heat can help some regions deal with winter peak electrical demand, particularly when deployed in older, less efficient buildings that tend to have higher heating needs.

In provinces such as Alberta and Saskatchewan that have cold climates, well-established gas distribution networks, and high levels of gas consumption for heating, hybrid systems reach a residential market share of 35 per cent and 28 per cent, respectively, in 2050, under a cost-optimal pathway, compared to 14 per cent nationwide.

Pulling back to the national scale and shifting to the commercial sector, the modelling results indicate much higher deployment of hybrid systems in commercial buildings compared to residential—such hybrid heating systems rise to capture 37 per cent of the national share of the commercial buildings market by 2040, and 50 per cent by 2050. This is in part because commercial and institutional buildings are generally larger and more complex, which translates into greater heating loads. Switching them from gas equipment to electric heat pumps often requires more significant upgrades, raising project costs.

From a system perspective, hybrid heating systems in commercial buildings can offer more peak-shaving value, with larger loads and operations that often coincide with daytime peak hours, which increases the value of gas availability to mitigate peak demand. However, the importance of hybrid systems for managing peak demand may be overestimated, as NATEM and other models don't fully capture alternative strategies to mitigate the cost of peak demand, such as distributed energy resources and interprovincial trade.

By 2050, in our modelling results, hybrid heating systems burning low-emission gases are nearly the only context in which Canada's buildings are consuming gas—they make up the entirety of gas demand in the existing distribution system. Under a cost-optimal net zero pathway, all exclusively fossil-gas space heating is phased out by 2050.

Other approaches to peak shaving and load shifting could lower electricity capacity needs with less risk of locking in costly gas infrastructure.

So while hybrid heating systems maintain a role for gas networks, those networks are delivering very low volumes of fuel. The quantity of gas used for space heating in residential buildings still drops by 96 per cent, from an average of 4.7 GJ per month in 2020 to an average of 0.2 GJ per month in 2050. In commercial buildings, consumption drops 88 per cent, from an average of 122 GJ per month in 2020 to 15 GJ per month in 2050.

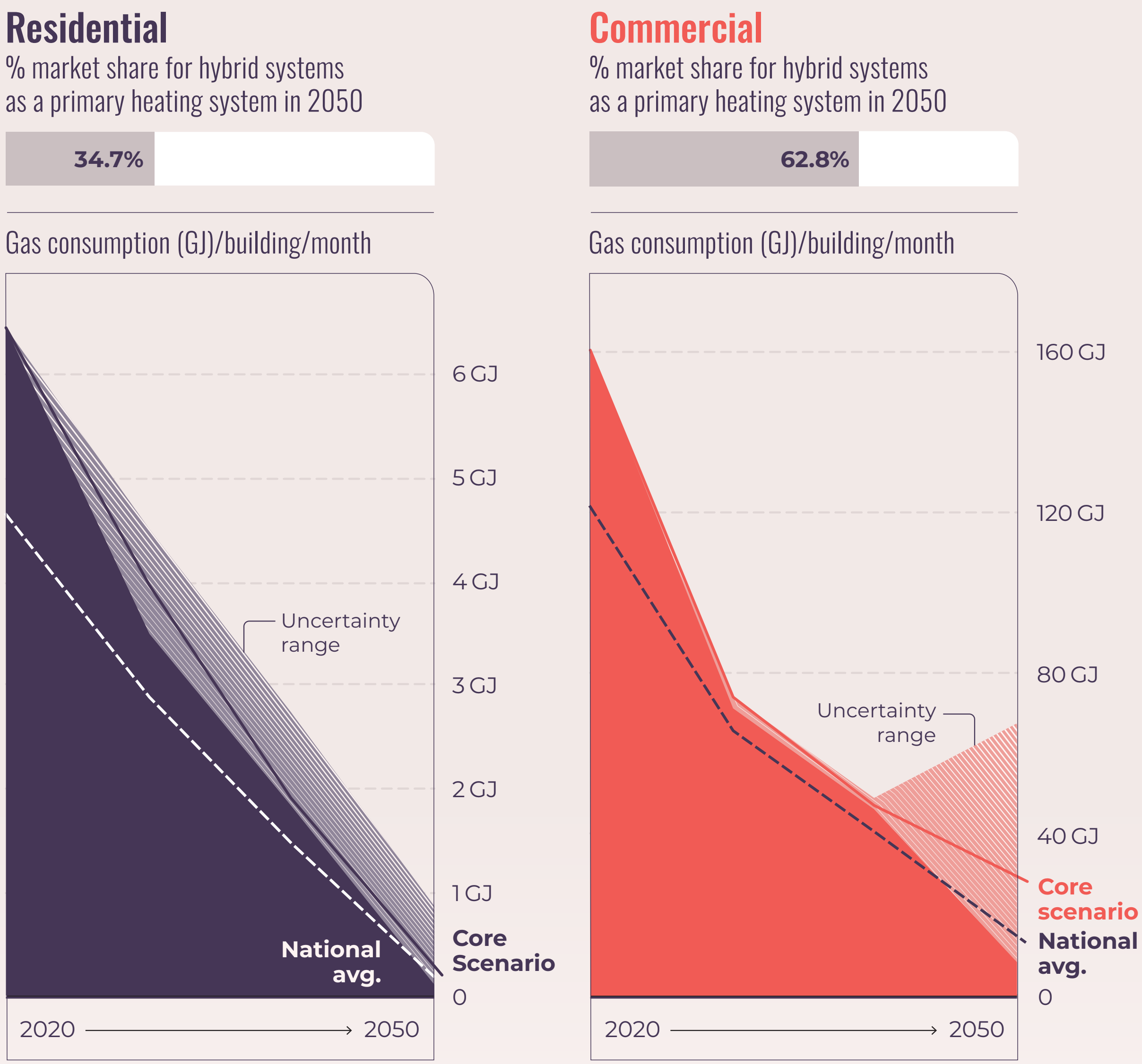
In Alberta, which sees the highest uptake of hybrid systems in 2050 (35 per cent of residential market share by 2050), residential gas consumption nonetheless plunges by 83 per cent over the same period (*see Figure I*). Even where buildings retain a gas furnace, heat pumps are covering most of the heating load.

As for commercial buildings, while hybrid systems rise to make up 50 per cent of national market share by 2050, gas consumption from commercial buildings still declines, falling by 91 per cent nationally by 2050.

All of this points to a future of profound upheaval for Canada's gas systems—even in regions where hybrid heat may play a significant role. Some buildings may still use gas for space heating in a net zero future, but only during the coldest days or weeks of the year. Gas utilities will find it complex and challenging to recover ongoing network maintenance costs from a customer base that is smaller and uses less gas.

Figure 1

Even in Alberta, the province with the highest projected share of hybrid fuel systems by 2050, gas consumption is projected to fall



Uncertainty in the extent of gas use in the commercial sector widens between 2040 and 2050, but the particular shape of the distribution between 2040 and 2050 is a function of the model's mechanics. GHG reduction requirements in the model tighten over time and the model works in five-year timesteps. In one of the sensitivity analyses, 2040 is the point when cost assumptions result in a shift to more gas use.

Hybrid systems may appear optimal in some regions or contexts, but given the high costs of maintaining gas systems just to service peak demand, other approaches to peak shaving and load shifting could lower electricity capacity needs, with less risk of locking in costly gas infrastructure. As we discuss above, our modelling has limited representation of some of the newer peak shaving and load shifting options, so its findings for the cost-optimal levels of hybrid heating may be overestimated. In areas where hybrid systems could play a larger role, more granular modelling of regional pathways would help to better understand its costs and benefits compared to non-gas alternatives.

A larger role for hydrogen and biomethane comes with the risk of higher costs and reliance on less certain technologies

A cost-optimal pathway to net zero includes a modest role for some hydrogen and biomethane in building heat. A much larger role for low-emission gases in buildings is likely more expensive overall but could broaden the possibility of keeping existing gas infrastructure (furnaces in homes and pipelines in the ground) in use for longer. However, pushing for a bigger role for hydrogen and biomethane risks raising overall costs, and depends more on less-certain decarbonization technologies, while doing little to mitigate the need to invest in electricity capacity expansion.

To date, Canada's biomethane supply is fairly limited and expensive. In British Columbia, for example, ratepayers can elect to pay a premium of $7 per gigajoule for biomethane—about 30 per cent more than the price of fossil gas as of January 2024—to offset the emissions from their gas consumption. This price is below the actual additional cost to the gas utility, according to records provided to the regulator (*BCUC 2024*). Energir in Quebec also charges customers more for biomethane: as of October 2023, biomethane cost $19 per gigajoule compared to less than $3 per gigajoule for fossil gas.

Increased production capacity and importation are possible, at least in the near term. But given the feedstock constraints and competing uses we discuss above, a reliance on significant levels of biomethane for building heat could prove costly or difficult to deliver, which risks locking in higher costs to ratepayers, higher emissions, or both.

Blending hydrogen into existing gas supply systems risks under-delivering on greenhouse gas emissions reductions, unless utilities achieve much higher blending rates. Blends of five to 20 per cent by volume may require utilities to only slightly modify their existing networks. A 2022 National Research Council study concluded that, in general, up to 5 per cent blending can be tolerated anywhere, and up to 20 per cent in distribution or regional transmission pipelines with no critical downstream appliances (*Yoo et al. 2022*). However, such blending rates mean that the end product is still predominantly methane gas, not hydrogen, driving only marginal greenhouse gas savings. Moreover, when hydrogen displaces methane in a gas network, it also reduces overall energy content (hydrogen has only about one third the volumetric energy density of methane gas), such that a 20 per cent hydrogen blend only reduces greenhouse gas emissions by 6 to 7 per cent. Blending at low levels is therefore not a viable long-term pathway.

A strategy for building decarbonization that relies on yet-unproven technologies risks failure if the technologies' potential is not realized.

Higher-ratio blends or pure hydrogen would likely require more substantial modifications and new pipes, and homeowners would also need to upgrade or switch to hydrogen-compatible appliances (*Baldwin et al, 2022*; *Topolski et al. 2022*). Pure hydrogen boilers for homes are not yet commercially available. Pilots of pure hydrogen for heating have started in some places, but the idea is in the early stages. Two pilot projects in England for 100 per cent hydrogen heating, for example, were recently cancelled due to community opposition to the trials and inadequate local hydrogen supply. A similar pilot in Scotland is still in the planning phases (*Ambrose 2023*).

Committing to a pathway that involves the future use of pure hydrogen for heating would mean relying on end-use technologies that have not yet been deployed at commercial scale, and building new gas distribution networks or retrofitting existing ones. The extent to which existing pipes can tolerate pure hydrogen without embrittlement and excessive leakage is uncertain. And regardless of equipment costs, the costs of hydrogen itself—especially given that other sectors will be competing for it—may be enough to make hydrogen heating an uncompetitive pathway relative to alternatives.

A strategy for building decarbonization that relies on yet-unproven technologies risks failure if the technologies' potential is not realized. Provinces would then need to pivot to other options despite sunk costs and additional costs of delay, or risk missing climate targets.

Implementation uncertainty exists, of course, for all decarbonization strategies. For example, the extent to which energy retrofits can be completed, or the number of heat pumps that can be installed, depends on the corresponding investment and effort. But low-emission gases are at an earlier stage of their development, and their potential is less clear.

In any case, a larger role for low-emission gases in the buildings sector doesn't avoid the need to extensively build out electricity system capacity. Our modelling finds that using more of Canada's scarce supply of low-emission gases in the buildings sector requires greater electrification in other sectors, such as heavy transportation and industry, to meet emission targets. The required scale of the electricity system build-out ends up being similar.

Continued growth of the gas network is inconsistent with cost-effectively reaching net zero

Given the rapid shift away from gas consumption in buildings along a cost-optimal pathway to net zero (*see Figure H*), provinces that continue to expand their gas distribution networks could jeopardize Canada's climate goals or raise the cost of meeting them.

This conclusion is consistent with numerous other studies, including the following:

- In its report *Net Zero by 2050: A Roadmap for the Global Energy Sector*, the International Energy Agency concludes that, while gas pipelines will still have a role to play, additional investment in new gas pipelines is not indicated given the projected decline in fossil fuel demand (*IEA 2021*).
- In a 2022 analysis, the International Institute for Sustainable Development (IISD) found that declining fossil fuel demand may lead to stranded assets if utilities are unable to recover infrastructure expansion costs— leaving ratepayers or governments on the hook (*Cameron et al. 2022*).
- In a 2021 presentation, global research and consulting firm The Brattle Group asserted that accelerating electrification will increasingly disrupt conventional gas utility business models, and that companies will face increasing risks to recovering the capital investments they need to expand their networks (*Graves et al. 2021*).

- A recent study in the journal Nature Energy concludes that a continued expansion of gas infrastructure that has a decades-long service life will hinder the transition to renewables, while resulting in "carbon lock-in" (*Kemfert et al. 2022*).
- After three years of evidence and consultation, Massachusetts' future of gas regulatory proceeding came to a close in 2023. The regulator's final decision includes direction to "minimize investments in the gas pipeline system that may be stranded costs in the future as decarbonization measures are implemented," beginning by considering non-pipeline alternatives (*Massachusetts DPU 2023*; *Energy and Environmental Economics Inc. and ScottMadden Inc. 2022*).

The potential economic viability of hybrid heat in some regions of Canada does not justify the costs of expanding the gas system in those areas. Adoption of hybrid heat can be particularly valuable in existing buildings as a stepping stone to electrification, particularly because older buildings tend to be less efficient and their larger energy needs contribute more to peak heating demand. But this is not necessarily true for new buildings, and extending gas networks to them carries risks with less potential benefit to the system as a whole.

The potential economic viability of hybrid heat in some regions of Canada does not justify the costs of expanding the gas system in those areas.

At the consumer level as well, in many contexts in Canada and the United States, all-electric new buildings are already a more cost-effective option (*Miller et al. 2023*, *Billimoria et al 2018*; *McDiarmid 2022a*).

As we discuss in the next section, further growth of the gas network presents serious risks, both for gas ratepayers and Canada's climate goals. Cost-effectively meeting net zero means that new gas infrastructure could be unused or underused before it is fully depreciated—typically over 40 to 50 years—resulting in a stranded asset that someone will be left to pay for. That someone could be a steadily contracting base of ratepayers, but it could also include utility shareholders, governments, or a combination of the above.

SECTION 02

The current trajectory of building heat compared to a **cost-optimal net zero pathway**

A cost-optimal path to net zero consistently includes extensive electrification, contracting gas demand, limited long-term use of hybrid systems, and significant investments in electricity capacity and energy efficiency. Each of those elements has important implications for Canada's policymakers, regulators, and utilities. This is particularly the case because, despite some recent progress, Canada's buildings sector and its electricity and gas systems are not yet on that cost-optimal net zero path.

In this section, we unpack the implications of this misalignment for the buildings sector, for energy utilities and regulators, and for Canada's clean energy transition.

2.1 The status of building heat in the clean energy transition

Getting closer to the cost-optimal pathway to net zero described in *Section 1* would require a major shift in direction from where the buildings sector and gas and electricity systems have been trending over the past 10 to 15 years.

Canada's emissions from building heat continue to rise

Greenhouse gas emissions from Canada's buildings sector grew 8.8 per cent between 2005 and 2022, and existing climate policy has proven insufficient to reverse the sector's rising emissions. Nearly every other sector is successfully reducing emissions, yet rising emissions from only two sectors—buildings and upstream oil and gas—undercut the other sectors' progress to date (*Stiebert and Sawyer 2023*).

Greenhouse gas emissions from Canada's buildings sector grew 8.8 per cent between 2005 and 2022.

Previous research from the Canadian Climate Institute has found that the buildings sector's emission trajectory is not on track to meet Canada's 2030 target—let alone the 2050 net zero target (*Sawyer et al. 2023*). That's even after accounting for all existing policies that could lower emissions from buildings, such as carbon pricing and government programs supporting energy retrofits and clean technologies. To meet the 2030 goal, buildings-sector emissions would need to decline to between 26 to 31 megatonnes of carbon dioxide equivalent below 2005 levels. Our analysis found that existing legislated policies would barely yield half (13 megatonnes) of the required reductions.

If Canada cannot rein in emissions from buildings, it risks either missing its climate targets or requiring a disproportionate effort from other sectors, raising the energy transition's overall costs.

Although there are signs of progress, the push to build bigger electricity systems remains nascent and uneven

The electricity sector is Canada's emissions-reduction poster child. The sector's greenhouse gas emissions have plunged 56 per cent since 2005, driven in large part by efforts to phase out coal power. Provinces such as Ontario, Alberta, Saskatchewan, Nova Scotia, and New Brunswick still have further to go, and each is facing unique challenges, but the collective progress and momentum on clean electricity is undeniable.

That said, when it comes to expanding systems to meet the steep load growth associated with broad electrification, policy in many regions is still in its infancy. In some, it is absent. While as recently as 2021, almost no Canadian utilities had plans for significant expansion, a string of announcements this past year signalled more ambitious plans for growth:

— The Province of Ontario released *Powering Ontario's Growth*, a guidance document that directs the Independent Electricity System Operator to procure numerous types of new supply to meet growing industrial demand for clean power and demand from household electrification (*Government of Ontario 2023*).

— Hydro-Quebec committed to an historic spending and capital investment plan of between $155 and $185 billion, similarly aimed to prepare its system for the demand that is coming, and to enable the province to continue to be an exporter of power (*Hydro Québec 2023*).

— In 2024, BC Hydro announced a $36-billion capital expenditure plan (*BC Hydro 2024*) in its own infrastructure and issued the first new call for power from independent producers in 15 years as part of a series of calls, each anticipated to drive $2.3 to $3.6 billion of private investment in generation capacity (*Government of British Columbia 2024*). The Government of British Columbia is also examining how it can prepare its power system for accelerated electrification via initiatives such as its climate-aligned energy action framework and BC Hydro Task Force.

Some provinces are including planning scenarios that consider high rates of electrification (British Columbia, Nova Scotia, Ontario, Alberta). Some are exploring significant expansion of offshore renewables (Nova Scotia, Newfoundland and Labrador). Some are introducing or considering electricity planning and governance reforms (Ontario, Nova Scotia), or intending to produce net zero energy roadmaps that can inform and guide electricity system expansions (Manitoba, New Brunswick).

This progress is encouraging. But if Canada is to prepare its electricity systems for growing demand, governments, utilities, and regulators must expand the scope of this work and accelerate its implementation.

Meeting climate goals in a cost-effective way requires that gas networks stop growing, yet gas utilities continue to lay pipe and add customers

The clean energy transition challenges Canada to take a sober and systematic approach to the switch from gas to electricity in building heating, while ensuring reliable and affordable heating for consumers. As we discuss above, taking the lowest-cost path to achieve Canada's 2050 climate target means it will be necessary to stop expanding gas distribution networks.

The clean energy transition challenges Canada to take a sober and systematic approach to the switch from gas to electricity in building heating.

And yet, across the country, gas utilities are continuing to expand (*see Figure J*).

Regulatory filings that disclose gas utility assets offer a window into the scale of ongoing investment in Canada's gas distribution systems. A gas utility recoups the costs of its regulator-approved assets plus a defined rate of return on these assets from customers. The recouping of costs is spread over the financial lifetime of the assets. For pipelines, for example, this is typically 40 to 50 years. After this time, infrastructure may still be used as long as it is safe to do so, but it has been fully paid off by ratepayers.

The rate base for Canadian gas customers, meaning the assets still to be paid off, reached approximately $29.5 billion in 2022. A growing rate base is one indicator of the extent of ongoing investment in gas utility networks. It includes undepreciated property, plant, and equipment assets, as well as some financial assets.

Over the last decade of available data, the total reported rate base of Canadian gas utilities grew by about $8.5 billion (inflation-adjusted)—a 40 per cent increase[5]. Most of that increase occurred in provinces with large established gas networks, such as Ontario, British Columbia, Alberta, and Saskatchewan (*see Figure J*).

Some of those new assets are pipeline extensions. For example, FortisBC, SaskEnergy, and CentraGas (Manitoba) have collectively added more than 10,000 kilometres of pipeline to their networks since 2013.

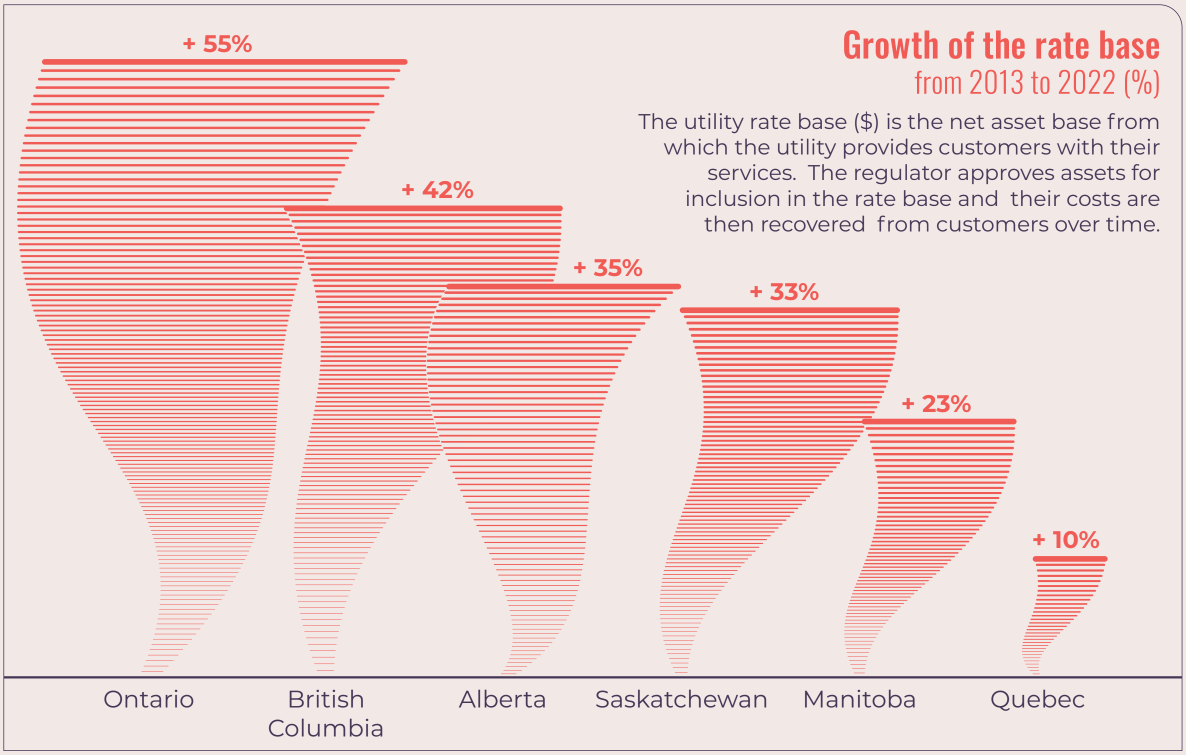
Gas utilities are also steadily growing their customer base. Gas companies across Canada added about 778,000 new customer accounts to their networks between 2013 and 2022, representing 12 per cent growth over that ten-year period.[6]

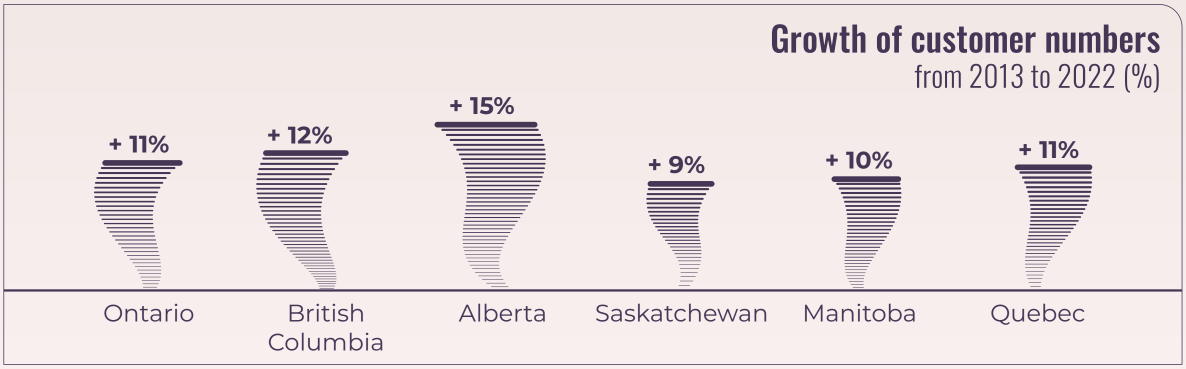
Between 2013 and 2022, FortisBC, British Columbia's largest gas utility, grew by an average of over 13,000 customer accounts each year. And Ontario's gas providers together added an average of 43,600 additional customer accounts per year between 2013 and 2022.

5. *We arrived at our calculations regarding the size and growth over time of rate base assets by consulting regulatory filings with eight regulators and the financial statements of 11 utilities for the years 2013–2020. Information on rate base assets was available for all jurisdictions and years except for 2021–2022 in Manitoba, and 2013–2015 and 2020 in Nova Scotia. For those years, we calculated the average annual growth rate and linearly extrapolated for the missing data points.*
6. *We calculated the growth in customer numbers by consulting the regulatory filings with eight regulators and the sustainability reports and websites of 11 utilities for the years 2013–2022.*

Figure J

Gas networks are growing, increasing costs that must be paid for and maintained by the customer base





2.2 The stakes of being off-track

This trend of continued expansion of gas systems while underinvesting in electricity systems presents risks for both ratepayer affordability and system reliability. If electricity systems do not grow fast enough, and gas networks continue to grow despite uncertainty about their long-term use, Canadian rate-payers face the risk of higher rates, reliability concerns, or both.

Continued gas network growth is creating risk by adding liabilities that must ultimately be paid for

Even as the clean energy transition continues apace, gas utilities are still laying pipelines and growing their distribution networks, despite the looming risk of a declining customer base as more consumers switch to electric heating technologies.

Gas utilities are still laying pipelines and growing their distribution networks, despite the looming risk of a declining customer base as more consumers switch to electric heating technologies.

Because companies amortize their infrastructure investments over decades, infrastructure decisions taken today will affect affordability for consumers now and for decades to come. The broad base of gas customers typically subsidizes new connections to existing gas networks, assuming existing customers will benefit from sharing the fixed costs of the gas network across a larger base. But this only benefits all gas customers so long as the gas customer base keeps growing and new customers continue to use gas for decades after connecting.

For many new connections, the cost is covered by gas ratepayers if the anticipated revenue from the new customer over a given time period (typically, 40 years) is equal to or greater than the cost of connecting them to the gas network and serving them over that time. The cost accounting typically assumes the new customer will stay connected to the system for the full time period. When gas utilities extend their networks into rural regions, however, projected new customer revenue—even when assumed to last over 40 years—will only cover a small part of costs. Direct government support for network expansion has enabled rural expansion in some provinces (for example, Ontario, Alberta, Saskatchewan), where otherwise connections would be uneconomic.

Under these arrangements, there is little incentive for a developer to choose electrification, even where the electric option would be cheaper for the eventual building occupants, since the cost of gas connection is free to the developer and the energy bills are paid by the occupants. But this choice exacerbates risks for gas customers. Should these new customers use less gas than anticipated (for example, by installing a hybrid system down the road) or leave the network before the end of the 40 years' anticipated revenue from their bills, the remaining customer base could be left covering the remaining cost of connecting them to the network through higher rates.

Ongoing network expansion presents significant risk to all provinces with gas systems.

As our analysis in *Section 1* shows, falling gas demand is part of a cost-optimal net zero pathway across all sensitivity analyses. A declining number of gas customers will strain a given gas utility's ability to recover the costs of its historical and ongoing infrastructure investment. This risk of stranded assets is most acute for new investments in infrastructure, such as pipeline replacements and expansions. Newer infrastructure has less accumulated depreciation. Its higher remaining asset values relative to older infrastructure represent higher liabilities for current and future customers to bear, should the assets become stranded due to disuse or underuse before the end of their expected lifetime.

Ongoing network expansion presents significant risk to all provinces with gas systems. However, the extent and age of infrastructure, like the prevalence of gas heating, is highly variable by region. Provinces with newer or recently replaced or expanded systems face higher risks to customer bills as more infrastructure has yet to be paid off. And those provinces with a small user base face an elevated risk that these liabilities will land heavily on remaining customers if and when assets end up stranded. Risks can therefore be especially pronounced for provinces with smaller and newer gas networks, such as New Brunswick and Nova Scotia.

Underinvesting in electricity systems compromises Canada's climate targets, energy reliability, and economic opportunities

Canadian electricity systems that do not prepare for their customers' evolving energy needs—including improving their resilience to intensifying climate-related impacts—could be prone to service disruptions and additional costs to ratepayers while pushing Canada's climate targets out of reach.

Faster-than-expected electrification has already driven some Canadian electricity utilities—for example, BC Hydro and Newfoundland and Labrador Hydro—to update their forecasts and undertake new planning ahead of schedule (*Butler 2024*). Demand for and competition over new electricity supply has never been stronger, and provincial governments are already having to make choices about who gets access. In 2023, Quebec moved to a selective process for industrial connection requests above five megawatts (*Government of Québec 2023b*; *The Canadian Press 2023*) while British Columbia recently suspended connection requests from cryptocurrency miners (*Government of British Columbia 2022*).

Prompt, clear, and decisive policy, coupled with strong future-proofing of grid investments, can unlock opportunities, reduce overall costs, and smooth the energy transition.

If demand outpaces system growth, then these tensions will only grow. They could also lead to lost economic opportunities. Less clean electricity available for new industrial demand could drive investment abroad, as industries increasingly make access to reliable and affordable clean power a condition of their investment in Canada (*Beugin and Gullo 2022*).

Prompt, clear, and decisive policy, coupled with strong future-proofing of grid investments, can unlock opportunities, reduce overall costs, and smooth the energy transition—avoiding a more abrupt shift further down the road (*Bataille et al. 2015*). Absent these proactive moves, Canadian electricity systems' ability to continue to support Canada's clean energy transition while continuing to deliver reliable, affordable service will be strained.

An incremental approach to the transition risks elevating costs, introducing reliability issues, and locking in dead-end pathways

Some actions that are being implemented or piloted today—such as more energy-efficient gas furnaces and blending modest percentages of biomethane or hydrogen—may reduce emissions somewhat in the short-to-medium term. But not every action that reduces greenhouse gas emissions in the near term is necessarily compatible with the long-term goal of reaching net zero in a cost-effective way.

Not every action that reduces greenhouse gas emissions in the near term is necessarily compatible with the long-term goal.

Strategies that only reduce emissions incrementally can be a dead-end pathway (*Net-Zero Advisory Body 2020*). If the choice of pathway does not drive the necessary transformations of the electric and gas systems nor sufficiently increase adoption of needed end-use technologies, it can deepen the commitment to a system that does not meet the need for deep emissions reductions and is incompatible with Canada's clean energy transition.

Continued inertia and a lack of bold action carries significant risk. Either Canada fails to deliver on its international commitment to reduce greenhouse gas emissions, or Canadians effectively pay twice: once for incremental and insufficient solutions, and again to eventually correct course and build out the necessary infrastructure.

SECTION 03

Limitations of existing policy and institutions

This section explores why the trends we discuss in Section 2 are unlikely to change under current policy and regulatory approaches, and elaborates the risks that continued inertia poses to Canada's climate goals and the success of its energy transition.

The bulk of the policy discussion in this report is focused on provincial governments. Reaching net zero for building heat in the territories has particular opportunities and challenges that are not covered here in detail.[7]

3.1 Limitations of current climate policy

Climate policy is making a difference in the buildings sector. Without it, greenhouse gas emissions from building heat would be even higher, and fewer Canadians would have access to the cost savings and other benefits of energy retrofits and cleaner technologies. But to date, climate policy has not been sufficient to get the buildings sector on track to meet Canada's climate goals.

Existing climate policies are insufficient to address rising emissions from the buildings sector

A suite of federal, provincial, and territorial policies encourage Canadians to heat their homes and businesses more efficiently and switch from fossil fuels to electricity. But gaps remain, and implementation is fragmented and slow. Economy-wide climate targets, plans, and policies are in place in some places and not others, and often lack consistency and specificity.

7. *The implications of the clean energy transition on Indigenous communities, particularly in remote settings, is also not addressed in detail in this report. Forthcoming work from the Institute, in partnership with Indigenous Clean Energy, will address some elements of this issue. Healthy Energy Homes will explore ways to improve housing stock in Indigenous communities in order to address poor Indigenous health outcomes, reduce emissions, and support reconciliation (Canadian Climate Institute n.d.).*

In the context of a cost-effective pathway to net zero, existing policies fall short in four main ways:

1. **Limited adoption and implementation of climate targets.** While the federal government has legislated its commitment to net zero by 2050 (*see Box 1*), only a handful of provinces have followed suit (*Linden-Fraser 2024*). Notable examples include Prince Edward Island, Nova Scotia, and British Columbia; however, British Columbia's legislation currently only requires the province to reduce greenhouse gas emissions 80 per cent by 2050 (*Government of Prince Edward Island 2024*; *Environmental Goals and Climate Change Reduction Act, Nova Scotia 2021, c.20.*, *Climate Change Accountability Act, Statutes of British Columbia 2007, c.42*). Where provincial and territorial targets exist, they aren't necessarily connected to clear plans, and provincial and territorial climate plans often lack detail on the necessary changes in energy use.

2. **Policy inconsistency.** Demand-side policies focused on building electrification are a patchwork, and rebates for energy retrofits and heat pumps vary significantly by province and by municipality. Policies that support energy efficiency and electrification in buildings, such as net zero building codes, building performance standards, and supports for heat pumps, are common in provinces with strong climate commitments (for example, British Columbia's Zero Carbon Step Code, and strong heat pump incentive program uptake in the Maritimes) (*Glave and Wark 2019, Turner 2023*). But overall, policy implementation is a mixed bag across much of Canada, with gaps in access.

3. **Policy uncertainty.** Existing programs, such as rebates for energy retrofits, are often funded for short terms. The stop-start pattern of incentive programs makes it difficult to maintain momentum in consumer demand and to maintain the ability of heating, ventilation, air conditioning, and retrofit industries to respond (*Miller et al. 2023*). Broader policies such as carbon pricing, which would drive increased electrification, rarely look further than a decade down the road, whereas purchases of energy-using equipment and the planning of gas and electricity systems routinely carry implications well beyond that time horizon.

4. **Limited attention to gas system infrastructure.** Little to no policy focuses directly on limiting the build-out of gas supply infrastructure to avoid stranded assets and protect future ratepayers. Some municipalities (for example, the municipalities of Greater Montreal and the City of Prévost) have started to prohibit gas hookups to new builds, but progress is slow and

can be contested by gas utilities (*Communauté métropolitaine de Montréal 2024*; *Le Devoir 2023*). In some cases, policy is even pushing in the opposite direction, encouraging more and continued gas use. For example, some governments continue to subsidize gas network expansion. Since 1973, the Government of Alberta has funded the Rural Gas Grant program, which offsets the cost of providing new rural agricultural and domestic gas service (*Federation of Alberta Gas Co-ops Ltd. 2022*). In 2021, the Government of Ontario announced a $234 million expenditure on expanding the gas distribution system, connecting 43 communities to the gas network at a cost of $26,700 per connected household (*Government of Ontario 2019*; *Government of Ontario 2021*).

Climate policies alone are likely not enough to drive change in regulated energy systems

In less regulated markets, government climate targets and policies would send a strong market signal, influencing investment decisions and shifting businesses and households onto a lower-carbon path. But the business of providing gas and electricity is tightly enabled and constrained by utility regulation.

Energy utilities provide essential services. Recognizing that they are natural monopolies, regulatory oversight is in place to ensure their services are delivered reliably and at a fair cost. This means that the regulators that oversee energy utilities, and the rules that enable and constrain those regulators, play an important role in either amplifying or constraining the market signals from climate policies.

Even with stronger demand-side climate policies, action focused only on end-use consumers is unlikely to transform the electricity and gas systems to the extent needed to align the provision of building heat with net zero. Demand-side policies and falling clean-technology costs may accelerate building electrification, but on the supply side, traditional regulatory approaches risk the continuing growth of gas networks and the insufficient growth of electricity grids.

3.2 Limitations of current utility regulation

Utility regulation will play an important role in determining the pace and cost of the clean energy transition for building heat. But provincial and territorial governments haven't fully prepared their utility regulators for that task. The extent of change required to switch building heat from fossil fuels to clean energy, combined with the fact that regulator mandates and practices predate the age of climate action, mean that the laws, regulations, and policies that determine energy utility oversight can be ill-suited to the needs of the energy transition, and even act as a barrier to it.

The long life of energy equipment and infrastructure means that decisions made today have long-lasting repercussions.

While the energy transition will play out over decades, the decisions that regulators are making today will have long-lived significance. Consider that the average Canadian household will purchase a new vehicle every eight years. That same family's furnace or heat pump could last for 20 to 30 years. The lifetime of a gas pipeline is even longer: a new or replaced pipe is paid off over 40 or 50 years and can often keep functioning past that time. The long life of energy equipment and infrastructure means that decisions made today, particularly in gas systems, have long-lasting repercussions.

Slow and steady growth in demand for gas and electricity has been a foundational expectation of energy utilities for decades, but that assumption does not hold for the clean energy transition

Canada's ability to meet its climate goals rests not only on climate policy that is focused on energy consumers, but also on provincial regulatory policy that is focused on the utilities that supply those consumers. Both energy utilities and the regulators that oversee them wield significant influence over the kinds of energy supplied and the way Canadians pay for it. (*See Box 2*: Energy utility regulation in Canada.)

In Canada, gas and electricity utilities are governed by business models and decision-making processes that have for decades operated under conditions of assumed slow, steady, and predictable demand growth. Decarbonizing building heat upends this foundational assumption. It challenges an approach to utility regulation and gas network investment cost recovery that assumes that gas demand will continue to increase indefinitely. And it presents significant challenges related to the need to rapidly build out the electricity system to meet rising demand.

Regulators are not adequately equipped to guide utilities through the clean energy transition

Since the 1960s, utility regulators have relied on the Bonbright Principles—named after economist James C. Bonbright—to guide their high-level decision making. The principles focus on cost-based pricing, avoiding a socially undesirable expansion of the rate base, ensuring infrastructure will be used and useful, providing a fair return for utilities (with stability and predictability of business), ensuring just and reasonable rates for consumers, and avoiding undue discrimination between different classes and types of consumers (*Bonbright 1960*).

These long-standing tenets remain relevant today, even as regulators may need to reinterpret some elements to guide decision making in the context of Canada's energy transition (*Utilis Consulting 2023*). For example, regulators have long considered what is fair—not only to current customers, but also to future ratepayers. Re-interpretation of this principle for the clean energy transition requires regulators to consider fairness over timescales of multiple decades, recognizing the potential impacts of today's decision on evolving risk for future ratepayers.

However, while the Bonbright Principles can be consistent with the needs of the energy transition, their application in this context starts to raise difficult questions that require policy guidance from governments. For example, regulators determine whether proposed asset investments are prudent or unwise, and approve calculations, such as depreciation schedules, based on the expected used and useful lifetime of those assets. But the energy transition raises fundamental questions about these assumed lifetimes.

Box 2

Energy utility regulation in Canada

In much of the country, gas and electricity—and, in some provinces, energy efficiency services—are provided by regulated utilities. Though the provinces differ in their approach to utility regulation, regulator mandates and responsibilities tend to include some common elements.

Regulators are responsible for ensuring energy utilities provide safe and reliable energy at a just and reasonable cost to the ratepayer. Because utilities holding regional monopolies generally operate electric and gas grids, regulators act as a proxy for the competitive market. (One notable exception to this is Alberta, which has a competitive electricity-generation market. Ontario also has some elements of a competitive market for generation). Regulators' focus is primarily economic, ensuring both a fair rate of return for utilities and reasonable rates and reliable service for the customers they serve.

In the regulated aspects of their business (for example, the delivery of electricity and/or gas to customers), utilities earn a predetermined return on investments that the regulator agrees are prudent. Under this structure, regulators play a crucial role in determining what investments utilities are approved to make in the energy system.

Regulators are mostly independent agencies, but cannot exceed their legislated mandate.[8] A provincial or territorial government establishes a regulator's authority through legislation, as well as orders and directives; these can be, and have been, amended over time. A regulator can exercise discretion, but only within its prescribed mandate. If a utility perceives that the regulator has overstepped or failed to fulfill its mandate, it has the right to appeal.

Regulators deliver on their mandate through a quasi-judicial process that considers and balances the parties' competing needs. Proceedings are typically case-by-case and utility-by-utility, but can also involve more general lines of inquiry.

8. *Saskatchewan is an exception. The province has two Crown corporations—SaskPower for electricity and SaskEnergy for gas. An appointed Rate Review Panel makes rate change recommendations for both utilities to the provincial Cabinet, which issues final decisions. The system does not have the same hearings and processes as other Canadian regulators.*

Shortening them pulls costs forward in time, increasing costs today but limiting the risk that a smaller pool of future ratepayers are left paying high costs for infrastructure they no longer use. In the absence of clear direction from government on these questions, regulators have to date proceeded with caution.

In at least three key respects, the limitations of existing regulatory frameworks and the lack of guidance from governments constrain both energy utilities and regulators from enacting plans and making decisions consistent with a cost-optimal net zero pathway:

1. **Policy uncertainty:** While regulatory best practices prioritize consideration of future ratepayers, a lack of clear policy direction is contributing to inertia. Provincial and territorial economy-wide climate plans and targets often lack the clarity that regulators need to guide decision making. And even where climate targets exist, uncertainty with respect to their implications for future demand for electricity and gas infrastructure (for example, when gas utilities propose use of biomethane or hydrogen in the pipelines) can leave regulators without a sufficient evidence base to make decisions consistent with climate targets. A core component of this policy uncertainty is the inherent uncertainty of the energy transition itself. Even with a net zero mandate, regulators may not have sufficient basis to change their approach without guidance from the provincial government on available pathways and energy system priorities.

2. **Limited mandate:** Regulators tend to have mandates that focus primarily on safety, reliability, and economic efficiency. Climate objectives, which did not exist when these mandates were set, are typically interpreted as being out of scope, unless a government clearly specifies them in policy, legislation, or other guidance. This scenario leads regulators to exercise caution when evaluating future infrastructure needs that involve a significant departure from the status quo in service of climate goals. Yet, in the energy transition, innovation and a departure from status quo approaches are likely necessary to protect long-term energy affordability for ratepayers.

3. **Fragmented decision making:** Regulatory proceedings typically consider individual cases regarding specific utilities. A broader assessment of system-level dynamics would require regulators to consider a future where electric and gas energy systems follow opposite trajectories, with demand for the former growing and the latter declining. The lack of an integrated perspective constraints regulators' capacity to manage an energy transition with deep implications for both systems. And existing practices can

> also exacerbate this fragmented decision making. For example, the legal requirement to connect gas customers upon request—often included as part of the obligation to serve—presumes and perpetuates the ongoing expansion of the gas network. Requirements are often linked to distance from existing infrastructure, but can snowball as each connection or reconnection expands the area of obligation.[9]

Current regulatory processes can leave promising solutions unconsidered

Under current frameworks, energy utilities generally bring solutions to their regulators for review, and propose initiatives and investments that focus on their operations. This approach can fail to surface alternative services delivered by the competitive market, and more distributed, customer-oriented solutions such as household energy storage and thermal energy networks.

Managing peak demand mitigates costs for the whole system, but under current regulatory systems, clean-energy approaches to peak shaving and load shifting risk falling through the cracks. Some of these solutions—particularly those that depend on access to distributed energy resources such as demand-response programs and virtual power plants—may be provided by non-utility actors, such as aggregators.[10] These parties may have limited avenues to propose their solutions, or their solutions may rely on innovations and support from utilities that are not currently incentivized to provide them.

If regulators are only ruling on utility-proposed solutions, the outcomes may not always be cost-optimal. For example, under current incentives low-emission gases and hybrid heat solutions are sure to be more attractive to gas utilities than full electrification and alternative approaches to peak management—but may not always be in the best interests of ratepayers or the energy system writ large.

9. *An example of an obligation to serve in British Columbia: "On being requested by the owner or occupier of the premises to do so, a public utility must supply its service to premises that are located within 200 metres of its supply line or any lesser distance that the commission prescribes suitable for that purpose" (Utilities Commission Act, British Columbia 1996, c.473 , Part 28).*

10. *Aggregators bundle together resources from many smaller distributed energy resources (such as residential solar panels or batteries) to act as a virtual power plant, and then sell either the electricity or a service (such as energy storage, or ability to deliver during peak time) to a utility (IRENA 2019, Brehm et al. 2023).*

3.3 Why status quo inertia puts the energy transition at risk

The limitations of climate policy and utility regulation discussed above interact to sustain a status quo trajectory for building heat that does not align with a cost-optimal path to net zero. It points instead to rising greenhouse gas emissions, growing gas networks, and electricity systems that aren't growing fast enough.

Gas utility business models are predicated on network expansion

Gas utilities' existing business models and current regulatory structures mean that their incentives can be at odds with maintaining future bill affordability for consumers in the context of the energy transition. Because gas utilities realize returns based on the infrastructure they install rather than the fuel they sell, they have a direct economic incentive to pursue continued growth of gas infrastructure and new customers—even if the long-term usage case is uncertain.

In the regulated segments of their business, gas utilities are largely insulated from most market signals—including the prospect of declining gas demand. A gas utility will pass some of its costs—including the cost of the gas itself, and carbon price costs—straight through to its customers. The gas utility's profits do not depend directly on gas sales volumes. As long as a gas utility's distribution networks remain in place, customers remain connected to them, and the gas utility can still recover its fixed costs through rates, a decline in sold gas volume—for example, from some customers converting to hybrid heat—is not an immediate threat to the underlying business model.

A gas utility earns its profits via a predetermined rate of return on its infrastructure investments as approved by the regulator. To secure approval, utilities must convince the regulator that new infrastructure will be necessary and useful. But once infrastructure is approved, utilities can be reasonably assured they will earn a return on it even if that usage case does not bear out.

The regulator can serve as a check against the accrual of excessive liabilities in the form of infrastructure that does not prove sufficiently used and useful over its lifetime. But regulators are not only required to protect customers from rate increases; they must also protect utilities' ability to maintain an adequate business and support the level of investment that is required for continued provision of energy services. They must also provide the opportunity for gas utilities to earn a reasonable rate of return, and can only stop or delay adding new investment to customer bills if such investment is shown to be imprudent—for example, if it will be underused or is more expensive than an alternative. As we discuss above, regulators are often constrained in their ability to make these kinds of assessments in the context of the energy transition.

In a less regulated sector, market signals would reduce the incentive that companies would have to pursue a strategy of continued network expansion in the face of potential demand declines.

In a less regulated sector, market signals would reduce the incentive that companies would have to pursue a strategy of continued network expansion in the face of potential demand declines. But gas utilities are partially insulated from these kinds of signals. They therefore have a strong incentive to advocate for pathways that require ongoing system maintenance or expansion—such as hybrid heating or a shift towards low-emission gases.

Fewer new customers and a declining customer base in the future is the primary concern for gas utilities under their current business model, but falling gas demand in terms of total volume does create some challenges under existing gas rate design. Historically, fixed costs have been partly included in variable consumer charges for reasons of consumer preference and to avoid a regressive pricing model that disproportionately affects lower-income consumers. With declining gas usage, however, gas utilities will eventually need to seek approval to modify their rate structures or seek public subsidies to recover the costs of increasingly underutilized assets.

Gas utilities will likely continue to focus on expanding their networks because regulatory models limit their ability to diversify

Legislation typically limits the activities of regulated gas utilities to building and operating gas infrastructure and certain associated demand-side management initiatives. This restricts their ability to diversify in the face of declining gas demand.[11]

Gas utility companies can conduct other business under separate competitive arms. But the stable, regulated rates of return are reserved only for the regulated parts of the utility's business to ensure continued capital investment in the utility's core mandate of reliable service delivery.[12]

Regulators in different jurisdictions have variously interpreted gas utility attempts to establish new lines of business. For example:

- In the past, citing competition, regulators such as the British Columbia Utilities Commission excluded alternate energy services, such as thermal energy networks, from the gas utility's regulated business (*BCUC 2012: page 60*). The regulatory framework guidelines for thermal energy networks, are however currently under review in British Columbia (*BCUC n.d.*).
- In some regions, gas utilities can generate revenue by delivering demand-side management and energy efficiency programs through performance-based incentives. However, in other regions (Nova Scotia, New Brunswick, Manitoba), distinct entities or utilities deliver those programs.
- In British Columbia, the province's gas utility includes various biomethane investments in the regulated part of its business, enabling a return for the utility on their investment (*Fortis 2023*). But Ontario's regulator already considers biomethane a competitive space—thus excluding it from gas utilities' regulated business (*OEB 2009*).

11. Some gas utilities in the United States have started to explore diversification options to better position themselves in the clean energy transition. For example, Philadelphia Gas Works, a municipally owned gas utility, commissioned a study on their potential to diversify (Energy + Environmental Economics et al. 2021); Eversource in Massachusetts is piloting networked geothermal systems; and Vermont Gas has started to lease electric heat pumps and hot water heaters to customers as part of their business.

12. Regulators also ensure the unregulated business does not receive any undue advantage from the regulated business; operations, financing and resourcing must be kept separate.

— In Ontario, Enbridge tried to increase their role in electrification by including heat pumps in their rate base, but was denied by the regulator (*OEB 2021*). Traditionally, gas utilities must focus on savings to their own customer base. The system is not designed to consider broader cost savings from fuel-switching for the consumer (who is now no longer a gas customer), for the overall energy system, or for other parts of the economy.

Each jurisdiction is exploring and interpreting how these potential new regulated activities interact with current lines of business, and what they mean for protecting ratepayer interests. While there is likely a case to be made for a departure from the status quo, policymakers and regulators will need to carefully consider what changes are in the public interest and which add cost and unnecessarily crowd out private sector efforts.

Electric utilities lack incentives to support electrification and expand systems to meet growing demand

While the regulatory framework for the electricity system is more closely aligned with achieving net zero than it is for gas, there is still room to improve, for example by increasing flexibility for electric utilities to make innovative proposals for investments and rate design, and by enabling electric utility planning to be more responsive to evolving conditions (*Utilis Consulting 2023*).

Policymakers and regulators have not yet fully directed, empowered, or incentivized electric utilities to prepare for the increasing demand for power that electrification will drive.

An electric utility interested in enabling electrification must justify any associated expenditure to its regulator based on the benefit the investment will provide to its own customers and electricity system. Investment in new capacity can put upward pressure on electricity rates, and detailed project-by-project oversight for new electricity capacity is in place to protect ratepayers from imprudent investments. But because current regulatory structures limit electric utilities' ability to include progress toward climate goals and savings for gas consumers as benefits of proposed investments, these utilities can only play a limited role in directly supporting or enabling electrification.

As electricity utilities enter a new era in which they are widely understood to be lead actors in the energy transition, the growth imperative to handle widespread electrification can clash with an investment approach that has grown to prioritize caution to pass regulatory approval. Historically, some Canadian electric utilities have faced public scrutiny for building or planning to build capacity in anticipation of load that did not materialize. For example, in 2013, Manitoba Hydro's Conawapa hydro project was cancelled after a panel review concluded that their long-term projections were too uncertain (*McClearn 2022*).

Finally, the energy transition stands to shift the dynamic between gas and electricity utilities, which are both governed by the same energy regulator. After years of operating in parallel in contexts where they provide mostly distinct services, in certain regions and in some respects, they are now competing for market share. The best example of this may be the rivalry brewing between heat pumps and gas furnaces, and the implications each has for gas versus electric utilities. Challengingly, the energy transition also opens up other areas that may require more explicit collaboration, such as load forecasting or planning for hybrid systems.

Under declining gas demand, regulators' ability to protect ratepayers will face unprecedented challenges

The energy transition presents new challenges to regulators' longstanding mandates to make sure utilities provide Canadians with safe and reliable energy at just and reasonable rates.

A first challenge comes from falling gas demand, resulting in fewer customers on the gas system and increased rates for those who remain.

Under current policies and market conditions, consumer uptake of heat pumps is on the rise (*Turner 2023*; *Kanduth 2023*). And in many housing types and regions across Canada, heat pumps already save consumers money over their lifetimes compared to gas or oil furnaces and air conditioning (*Miller et al. 2023*; *McDiarmid 2022b*). Where efficient electric technologies, driven by climate policies and market forces, outcompete gas on a cost basis, households and businesses will increasingly switch to electric options. And, where they can, they may increasingly defect from the gas network altogether to avoid paying connection fees. If gas consumption continues to contract, the smaller number of customers that still rely on gas will shoulder the fixed costs of maintaining the network. And if the exodus from gas heat accelerates, absent policy intervention, the customers with the fewest financial resources or wherewithal to switch will find themselves stuck on the system and bearing escalating gas rates.

A scenario of falling gas demand and customer numbers also creates financial and competitiveness risks for gas-consuming businesses. For technical or financial reasons, some industrial customers, such as steel, cement, and chemical plants, may not be able to electrify as readily or as quickly as others. As residential and commercial demand declines, remaining industrial customers may need to pay more of the fixed costs to maintain the gas network.

Left unchecked, customer defection could significantly accelerate a rise in gas rates, and financial markets may contribute to it. Some lenders are starting to consider the potential risks associated with a long-term reduction in gas use. In reviewing the capital structure of Enbridge Gas, for example, a recent Ontario Energy Utility Board-commissioned assessment flagged that the utility's investors and credit rating agencies are "widely recognizing the potential long term reduction in natural gas use" (*LEI 2023*). That perception of increased risk could translate to higher debt costs for gas utilities, resulting in rate increases and the potential for further customer defection.

The second challenge relates to stranded assets. Where assets are no longer used, any number of actors could be left with their stranded costs, including:

- Future customers, if regulators and governments allow gas utilities to leave stranded costs in the rate base—even though they are no longer used.
- Current customers, if regulators accelerate depreciation of these assets.
- Shareholders, if regulators remove these costs from the rate base.
- Canadians, if governments compensate shareholders for the early retirement of otherwise useful assets, either as a proactive measure or a consequence of litigation.

However the costs are distributed across these groups, the prospect of stranded assets raises complex issues of incentives and fairness. To protect system reliability for remaining gas customers while shielding them from costly rate increases, regulators may need new approaches.

As we discuss in *Box 3*, even options such as hybrid heat systems that could maintain a significant customer base in the gas system raise difficult questions for regulators.

Box 3

For hybrid systems to play a larger role, regulators and utilities face a difficult balancing act

Hybrid systems could play a role in the clean energy transition in some contexts, particularly as a stepping stone to electrification. But implementation is not straightforward.

A regulator or government would likely need to introduce a subsidy of some kind to sustain interest in hybrid systems at scale, since customers would need an ongoing incentive to stay connected to the gas network even while they are using very low volumes of fuel. (An alternative approach would be to use delivered bottled fuel for gas backup.)

Rate design to support hybrid system uptake is a balancing act. It typically must incorporate subsidies to recover gas network costs in a context where gas customers are using minimal gas, while still discouraging customers from using it as their primary heating fuel. Gas service bills include both fixed costs (for example, recovering the cost of building and maintaining gas pipelines) and variable costs (for example, the cost of the gas sold). In most regions, a bill's variable charges partially cover fixed costs. Risk of consumer disconnection from the gas network grows as fixed costs increase (which is to be expected under a widespread shift to hybrid heat), as customers will likely prove reluctant to pay high fixed costs for minimal service, particularly during the warm-weather seasons when their heating system is off (*RMI 2022*).

Several Canadian utilities are testing strategies to incentivize and accommodate consumer adoption of hybrid heating. Hybrid heat initiatives to date include a collaboration between Hydro Québec and Énergir (*Séguin and Bigouret 2023*), and a pilot by Fortis BC in a region where they supply both electricity and gas (*FortisBC 2024*). In Quebec, Hydro Quebec led the way by agreeing to pay Energir $2.4 billion to convert customers to hybrid systems, in compensation for lost gas-ratepayer revenue. They sought regulator approval to reclaim costs from electricity ratepayers on the basis that keeping gas systems for back up during cold periods can reduce pressure on Hydro Quebec's grid.

Box 3 (continued)

In the pilot programs designed to date, electricity rates essentially cross-subsidize gas rates to help cover peak service demand.

However, several issues arise:

REGULATORY UNCERTAINTY

This use of cross-subsidization is a new approach, which comes with uncertainty over whether the regulator will allow costs that are outside of typical electricity distribution service expenses to be reclaimed from electricity customers (*Baril 2023*).

COST OPTIMIZATION

It is not guaranteed that such arrangements are cost-optimal from an integrated energy system perspective. Regulators could, and should, require the value of investments in hybrid heat to be demonstrated compared to other peak management alternatives, and regulators in different jurisdictions, or considering different situations, could make different decisions.

DISTORTED INCENTIVES

Allocating more costs to electricity rates can disincentivize business and household electrification.

EQUITY IMPACTS

On average, cross-subsidies may benefit higher-income households more than lower-income households. The type of heating system used in Canadian homes correlates with income, and with ownership status. On average, higher-income, home-owning Canadian households are more likely to heat with gas, and lower-income and renting households are more likely to heat with electricity. Only 28 per cent of Canadians in the lowest income quintile heat their homes with gas, compared to 56 per cent of homeowners in the highest bracket. This split is also similar between renters (27 per cent gas) and homeowners (52 per cent gas) (*Statistics Canada 2023*).

3.4 Continuing with business-as-usual utility regulation in the energy transition is risky

Current approaches to utility regulation are not well-equipped for the needs of the energy transition. Continuing with the status quo despite its limitations risks raising long-term costs for ratepayers and jeopardizes a cost-effective clean energy transition in Canada.

Ultimately, someone must pay for the costs of maintaining gas networks and stranded assets within them.

On the electricity side, delayed action on needed investments raises risk for Canadian households and businesses. Should increasing consumer demand for electric technologies outpace changes to the electricity system, it could strain reliability, significantly exacerbate costs, or both. These risks exist for both generation capacity build-out as well as the necessary investments to manage peaks and improve reliability, including infrastructure upgrades, energy and heat storage, energy efficiency, and demand management.

On the gas side, status quo utility regulation and the inertia in gas system expansion that it drives also carries significant risk. Ultimately, someone must pay for the costs of maintaining gas networks and stranded assets within them. Without policy intervention, ongoing investment in an increasingly underutilized gas system will yield higher costs for remaining gas consumers.

And this new context where gas and electricity utilities potentially find themselves in competition and/or collaboration may challenge regulators' ability to protect the public interest.

Letting competition play out between gas and electricity utilities will not necessarily yield favourable outcomes for ratepayers under status quo approaches. For example, a transition in which gas network defection occurs organically rather than being steered through novel rate designs and conscientious system planning could lead to electricity demand peaks that the system is poorly prepared for, to gas networks with wide distribution that only serve sporadic customers at high costs, or both.

On the other hand, explicit cooperation between gas and electric utilities might not necessarily prove optimal for ratepayers. For example, companies may negotiate cross-subsidies that allow them to maintain their current business models and infrastructure, but that may ultimately result in higher overall costs to ratepayers when compared with a future of growing electricity networks and shrinking gas networks. Utilities may also work to protect their regulated markets and limit opportunities for new actors, such as energy service companies, which risks raising costs for consumers.

If utility regulators are to continue delivering on their mandate of providing safe and reliable energy at just and reasonable rates, provincial governments must equip them to face the new challenges of the energy transition head-on. Regulators have a great deal of power to shape the future of Canada's energy system, including addressing the question of who will pay for it. If provincial governments do not enable regulators to exercise their influence in the service of meeting Canada's climate goals, they risk costlier pathways, worsening affordability, and failure to achieve our climate commitments.

SECTION 04

Opportunities for policy to drive change

Despite the significant barriers laid out in the last section, regulators and governments have tools at their disposal to align Canada's gas and electricity systems with a cost-effective pathway to net zero. This section outlines ways that regulatory action and government policy, particularly from provincial and territorial governments, can counteract the prevailing inertia.

4.1 Existing options and recent developments

Regulators and policymakers in Canada have policy tools they could use today to start planning more proactively for a clean energy transition for building heat. In just the past year, we note examples of regulators and policymakers in Canada starting to change the status quo using their existing tools, and even more examples of regulators and policymakers in the United States contending with the same issues.

Regulators have tools under existing authority to navigate the energy transition

Though the specifics vary by jurisdiction, broadly speaking, provinces and territories have endowed regulators with powers and responsibilities to oversee energy system planning that will be valuable through the clean energy transition. With current mandates, energy utility regulators may be able to:

- Initiate consultations, inquiries, or even general proceedings on the future of the gas network in their province. No Canadian regulator has done so yet, but in the United States, at least 10 regulators have opened such proceedings since 2020 (*Bagdanov 2022*). Massachusetts' regulator was the first to issue a decision in 2023 (*See Box 3*).

- When evaluating rate filings and decision processes for utilities' capital plans, request more detailed risk assessments on the potential for, and implications of, a declining gas customer base, a significant drop in demand per customer, and increasing electricity demand.

- Increase information sharing and insights on the implications of the energy transition, emerging technologies, and changing consumer behaviours for regulators' core responsibilities to ensure fairness and protect ratepayers, for example through the Canadian association of energy and utility regulators (CAMPUT).

- Consider new business and remuneration models and rate designs that reflect the needs of the evolving energy system and the implications of overlap in the energy services supplied by gas and electric utilities (*Seguin & Bigouret 2023*).

Under declining gas demand, regulators can also limit future liabilities from the gas network and better align its scale with the future customer base. Where prudent, regulators can act to prevent or constrain new gas infrastructure construction by:

- Denying approvals for new gas pipelines, and capacity expansions for existing lines, based on the expected fall in gas demand over the infrastructure's lifespan. For example, in December 2023, the British Columbia Utilities Commission (BCUC) denied a gas utility's request to invest in gas capacity expansion in the Okanagan on the basis that increasing gas demand could not be assured. The BCUC directed the utility to respond by July 2024, and show consideration of alternatives (*BCUC 2023*). The Ontario Energy Board had previously signalled concern around the risk of stranded assets when it denied a replacement pipeline in Ottawa in 2022 (*Beer 2023*).

- Extending the useful life of the existing network as far as safe and practical, to restrain growth in the remaining value of assets that still need to be paid for. For example, in a December 2023 decision, the Ontario Energy Board directed the gas utility to emphasize monitoring, repairing, and, in general, extending the life of its system, and ensure that it only pursues the most critical replacement projects (*OEB 2023*).

- Requiring cost-benefit comparison of new gas pipelines against packages of non-pipeline alternatives, such as targeted fuel switching and energy efficiency, thermal energy networks, and temporary supply-side measures such as bottled gas. For example, the Colorado Public Utilities Commission requires utilities with a customer base greater than 500,000 households to analyze at least five non-pipeline alternatives (*Sullivan and Murphy 2024*; *Nelson et al. 2023*).

Box 4

The future of gas in Massachusetts

In 2023, Massachusetts' Public Utilities Commission became the first American regulator to issue a ruling on their Future of Gas Proceeding (*Massachusetts Department of Public Utilities 2023*). After a three-year-long process, the gas regulator ruled that gas utilities must:

- file climate compliance plans with performance metrics every five years;
- study the feasibility of targeted electrification in the state; and
- demonstrate consideration of non-gas alternatives when proposing to replace or expand gas infrastructure

The regulator also ruled that gas utilities cannot use ratepayer money to promote gas use.

The regulator ruled out a significant role for biomethane due to cost and availability concerns. It also ruled out the use of hydrogen as a primary fuel source for home heating due to uncertainty and competition for use with other sectors. The regulator was not convinced that a broad hybrid heating strategy, funded by ratepayers, was viable, but hybrid heat was not explicitly disallowed.

Similar proceedings are currently underway in Oregon, Washington, Nevada, Colorado, Minnesota, Rhode Island, New York, and California (*Advanced Energy United 2023*; *Eversource n.d.*; *Gridworks 2021*; *California Public Utilities Commission 2022*; *California Public Utilities Commission 2023*; *Mihaly 2023*; *NYSERDA 2022*; *Colorado Public Utilities Commission 2022*; *Colorado General Assembly 2021*; *Vermont Public Utility Commission 2023*; *Cosgrove 2022*).

When approving new gas infrastructure, regulators can reduce risk and improve incentives by adopting accounting practices that assume lower usage and shorter potential lifetimes, and clarify who will pay the bill for the proposed project. For example, regulators could:

- Require builders and developers to pay for new gas connections that would serve their projects, rather than subsidizing the work from future ratepayers on anticipated 40-year revenues. For example, in December 2023, the Ontario Energy Board effectively reversed the long-standing norm that all gas ratepayers must bear the upfront cost of new gas connections. The regulator noted that anticipating 40 or more years of income from these new customers may no longer be a reasonable assumption under a clean energy transition and given increasingly affordable alternatives to gas (*OEB 2023*). The Board's decision follows similar actions in other jurisdictions, including California and Colorado.

- Shorten time horizons for necessary new infrastructure. When a utility must replace a pipeline for safety or reliability reasons, the regulator can require the company to adjust its anticipated useful lifetime. This limits the risk that future ratepayers will be left paying for infrastructure they no longer use.

- Consider introducing accelerated asset depreciation schedules and other accounting practices that more accurately reflect and apportion infrastructure costs and risks (*Bilich 2019*). For example, New York State's regulator now requires gas utilities to submit depreciation studies assessing the impact of accelerated depreciation schedules on both ratepayers and costs (*Bagdanov 2022*).

Without clear government direction and support, regulators would likely be hesitant to change long-standing practices.

Many of these tools are within regulators' existing powers, and could be exercised starting today. Still, without clear government direction and support, regulators would likely be hesitant to change long-standing practices, out of concern that a court may overturn their decision based on a utility's appeal.

Some energy regulators and policymakers are taking steps to consider the clean energy transition in their decision making

Though the work is nascent and uneven, regulators across the country are starting to ask electric utilities to explain how they will decarbonize their systems, and have begun approving updated plans based on rising projected electricity demand. In early 2024, for example, the regulator in British Columbia accepted an updated 2021 IRP from BC Hydro that highlighted the need to obtain additional clean power to meet its customers' future electricity needs cost-effectively (*BCUC 2024*).

Utility regulators, most recently in British Columbia and Ontario, are also starting to ask gas utilities to more seriously consider the clean energy transition, directing them to better manage risk and ensure that proposed new infrastructure will be used and useful in the future (*Harland 2024*).

Regulators are also starting to scrutinize gas utility proposals for clean-fuel blending for their economic viability and to call for greater clarity on the role of the gas network in the future and how to protect customers along the way (*BCUC 2024*).

But while these new initiatives could reduce greenhouse gas emissions and mitigate customer rate impacts, regulators are having to decide on their deployment without a clear picture of where they fit in each province's long-term net zero pathway, and how they will ensure long-term energy affordability for all Canadians.

4.2 The importance of provincial leadership

Without provincial initiative, the path to Canada's climate targets is likely to be slow, costly, and ineffective (*Linden-Fraser 2023*).

Strong climate policy—from legislated targets, to broad-based economy-wide measures, to utility- and consumer-scale policies—will be critical to Canada's success. Not only does policy help influence consumer and business decision-making, it also sends a clear signal to regulators, utilities, and other energy-system actors, informing their planning. The federal government can certainly help, but provinces can significantly strengthen the policy environment by adopting each others' successful policies and tailoring approaches to their specific challenges and opportunities.

But even with strengthened climate policy, unless provinces also address the regulatory framework for energy utilities, regulators may lack the clarity and resources they need to contend with the energy transition on their own.

Many voices are calling for provincial policy clarity

Without provincial initiative, the path to Canada's climate targets is likely to be slow, costly, and ineffective.

Even as some Canadian regulators express concern about the looming risks of the clean energy transition and the importance of coordinating responses, they are also calling for provincial leadership.

In a March 2024 decision on BC Hydro's Integrated Resource Plan, for example, the British Columbia Utilities Commission encouraged BC Hydro and FortisBC to improve their communication and coordination, but noted that it "cannot force the utilities to agree upon any given view of the future, and [does] not wish to be overly prescriptive on provincial planning issues that may be more appropriately in the domain of the government" (*BCUC 2024*).

Similarly, in a September 2023 decision, the Nova Scotia Utilities and Review Board approved the gas utility's rate application, but questioned if its growth plan was in line with the province's net zero goals. The Board noted that, while the clean energy transition raised pertinent questions for the continued viability of the gas utility, clarity on the role of gas in the transition was more appropriately the purview of the provincial government (*NSUARB 2023*).

In the past year, various independent task forces and expert panels have similarly called for more provincial government direction to facilitate improved long-term planning. Ontario's Energy Transition and Electrification Plan, for example, invited the government to produce an economy-wide vision for the clean energy transition, as well as provide "policy direction on the role of natural gas in Ontario's future energy system as part of [the government's] next integrated long-term energy plan" (*Electrification and Energy Transition Panel 2023*).

While energy regulators will grapple with the many challenges of the energy transition at the ground level, the levers of change are mostly in the hands of provincial governments. Their inaction or continued inertia will only make the problem worse.

Provincial direction to regulators is the missing piece

Some provincial governments are beginning to recognize the need to direct and empower their energy regulators, at least with respect to the electricity system.

For example, in early 2024, the Province of Nova Scotia announced plans to significantly restructure its utility regulation regime. The province would spin out a new Nova Scotia Energy Board from the original Utilities and Review Board, establish a new independent System Operator, and include in the new Energy Board's mandate the goals and targets in the *Environmental Goals and Climate Change Reduction Act*, including its 2030 and 2050 climate goals (*Government of Nova Scotia 2024*).

Also in 2024, British Columbia amended the Clean Energy Act to direct the British Columbia Utilities Commission to ensure the procurement of sufficient electricity to meet climate targets while also limiting electricity rate increases to the rate of inflation. The amendments are an important step, even as further work is needed on energy system planning to support the interpretation and implementation of the new directives (*Fransen et al. 2024*).

No province, however, has yet issued a long-term direction on what the clean energy transition means for the future of gas for building heat in their jurisdiction, or how gas and electricity systems both must transform to get on a cost-effective path to net zero.

This lack of direction carries significant consequences. For example, ongoing ambiguity around potential new lines of regulated business for gas utilities is contributing to inertia. Both significant expansion of their regulated lines of business and restriction to their current ones have pros and cons: expansion allows them to find a new path forward, but restricts the roles that electric utilities and other actors will get to play; restriction allows new players to enter, but leaves gas utilities as forceful advocates for the status quo of continued system expansion. A lack of clarity around these questions leaves both utilities and their regulators at a crossroads, and is contributing to inertia.

The limits of current climate policy, on the one hand, mean that existing market signals are not strong enough or consistent enough to drive gas demand down fast enough. The limits of current utility regulation, on the other hand, mean that regulators are not adequately equipped to prepare for the energy transition and the risk it could pose to ratepayers. And these two policy problems interact to keep energy systems on the wrong track.

Provinces risk ending up with underdeveloped or unbalanced energy systems that are not ready for what's coming.

Absent policy leadership, provinces risk ending up with underdeveloped or unbalanced energy systems that are not ready for what's coming, straining affordability and reliability. The continued expansion of gas networks exacerbates the risk of stranded assets and elevated costs for ratepayers, as well as costly emissions lock-in that either puts an unfair burden on other sectors or puts Canada's climate targets out of reach. And without careful attention from policy makers and regulators, the risk of exacerbating equity impacts will remain unresolved: low-income Canadians and renters will continue to face barriers to access energy savings for efficiency and clean technology, and the last customers on the gas system will likely be those with the least capacity to bear its costs.

To provide better policy leadership and needed guidance to energy sector actors, provincial governments are starting to commission independent pathway assessments and produce net zero energy roadmaps. Box 4 discusses these tools and their critical features.

Box 5

The role of pathway assessments and energy roadmaps

A **pathway assessment** is a study of the available and credible pathways to achieving a net zero economy by 2050. It is a valuable tool for ensuring an orderly energy transition, as it helps to evaluate choices and tradeoffs, identify priority actions, and bring key stakeholders together for evidence-based discussions. The insights gained from an independent pathway assessment—particularly one that includes a degree of regional assessment—can help drive a cost-effective transition.

Properly designed, a pathway assessment helps build consensus among stakeholders regarding these choices, and will help set a clear direction for the decarbonization of a province's heating system. Ideally, a pathway assessment is re-commissioned on a regular basis, and is not a replacement for the more detailed energy system planning that system operators and utilities undertake, instead acting as a clear input to that work, and a signal regarding where investments should be going.

To be useful to governments, regulators, utilities, and other actors, pathway assessments should be:

EXHAUSTIVE

A pathway assessment should consider all credible net zero pathways, regardless of established technology or pathway preferences, accounting for the inherent uncertainty of the transition. This could be accomplished by commissioning a pathway assessment from independent experts or by ensuring project scope is inclusive of all potential scenarios, considering uncertainties such as technology costs and availability as well as global climate action and oil prices.

COMPREHENSIVE

The assessment's modelling should include an evaluation of the greenhouse gas emissions associated with all aspects of the economy, the interactions with all types of energy sources (not exclusive to electricity), and regional differences within the province or territory.

Box 5 (continued)

TRANSPARENT

Model selection, scenario design, and the selection of inputs and assumptions should be done transparently, with the outputs from all considered scenarios available for public scrutiny.

CONSULTATIVE

It is critical to be thoughtful about the data inputs, scenario design, and assumptions employed in a modelling exercise. Many assumptions are highly subjective and should be determined in consultation with local subject matter experts and stakeholders (including electricity system regulators, energy utilities, government officials, labour and civil society organizations, consumer interest organizations, and municipal and external policy experts), as well as Indigenous rights holders.

HIGH-LEVEL

A pathway assessment should not seek to replace more detailed electricity system planning and modelling conducted by system operators and utilities, but instead provide credible scenarios as an input. A pathway assessment can use more detailed modelling, specific to a given power system, region, or sector, to enhance the inputs and assumptions it makes when considering different scenarios.

RECURRING

In order to ensure a jurisdiction's energy strategy remains relevant, a pathway assessment should be recommissioned on a regular schedule (perhaps every five years). This allows for the inclusion of new scenarios, consideration of changes in technology costs and availability, macroeconomic changes, and insights from more detailed modelling that looks at specific sectors, technologies and regions.

Box 5 (continued)

Provincial governments can develop **energy roadmaps** to guide their transition to a net zero energy system. The roadmap serves as a comprehensive strategy or high-level plan—it clearly articulates the government's overall vision and objectives, while focusing on near-term priority actions.

Such system-level energy strategies must be produced by an elected government, as energy sector actors, like regulators, do not have the authority or mandate to make the wide-reaching policy decisions that meaningful energy roadmaps provide.

Energy roadmaps are seeing increasing use in a variety of jurisdictions across North America, helping energy system actors to navigate the policy priorities of governments, and plan the necessary investments accordingly.

To help navigate the decarbonization of building heat systems, energy roadmaps should:

CENTRE NET ZERO BY CLEARLY ARTICULATING A 2050 NET ZERO OBJECTIVE IN THE ENERGY ROADMAP

This objective should also be reflected in the legislation that articulates the mandate for regulators, system operators, permitting and approvals authorities, and Crown utilities (see first recommendation, below).

CLEARLY ARTICULATE THE GOVERNMENT'S VISION, OBJECTIVES, AND ACTIONS

Set out a clear picture of outcomes that the roadmap is trying to achieve in 2050, five-year milestones along the way, the objectives that inform the roadmap, and the near-term actions that can achieve these objectives and the long-term vision.

PROVIDE REGULAR UPDATES

Ensure the roadmap, and the priorities it sets out, are updated at least every five years. This will be critical to ensure roadmaps stay action oriented, drive specific changes, and remain relevant to the evolution of the energy system.

Box 5 (continued)

ENSURE ALIGNMENT ACROSS ENERGY SYSTEM ACTORS

Require responsible entities or agencies to publicly report no less than biannually to the provincial or territorial government to outline how they are supporting the jurisdiction's net zero energy vision and to identify both progress and barriers.

MODERNIZE ENERGY GOVERNANCE AND REGULATION

Identify and provide direction on key reforms necessary to update existing energy governance and regulatory frameworks to align with the achievement of a net zero energy system.

SCOPE TO INCLUDE ALL ENERGY SYSTEMS

Provide direction on the necessary action and reforms for the full energy system (both electricity and gas systems), promoting integrated planning and resource deployment and tackling the full domestic energy mix that will be required in 2050. Energy exports can be considered out of scope for a roadmap.

DEVELOP A PARTICIPATORY ENGAGEMENT PROCESS

Ensure that Indigenous rights holders, key stakeholders, and the broader public have the support and resources to meaningfully participate in developing the energy roadmap, and the opportunity to inform the regular updates that take place.

CONDUCT REGULAR EVALUATIONS OF ACTIONS

In addition to five-year milestones and periodic updates to the roadmap, the government should commit to transparently reporting back no less than biannually, to transparently review the actions outlined and provide updates on progress.

For more information on best practices in pathway assessments and energy roadmaps, see the appendix of the Canada Electricity Advisory Council's report *Powering Canada: A Blueprint for Success* (Dunsky et. al 2024).

SECTION 05

Aligning building heat with net zero

As we've seen throughout this analysis, the clean energy transition has profound implications for the energy systems that provide gas and electricity to heat Canada's buildings. In this section, we step back to summarize the top-line conclusions this analysis yields, and then present a series of recommendations designed to help regulators and provincial governments navigate this transition in a way that protects long-term energy affordability and reliability for Canadians.

5.1 Conclusions

Canada's clean energy transition will fundamentally change how Canadians heat buildings, and transform gas and electric systems. Four overarching conclusions emerge from our analysis.

Electricity powers most space heating as Canada approaches net zero

Managing peak demand to keep electricity affordable and reliable will likely emerge as the central challenge facing electric utilities in this transition.

Across all regions and in all sensitivity scenarios, the story is the same: On a cost-effective pathway to net zero, most homes and businesses switch from fossil fuels to electricity to heat their spaces. The details vary province to province, but the pattern of substantial electrification is consistent everywhere.

Many provinces are making progress in cleaning up their electricity grid. But to support economy-wide decarbonization, all provincial electricity systems must get cleaner, bigger, and smarter—and quickly.

Indeed, managing peak demand to keep electricity affordable and reliable will likely emerge as the central challenge facing electric utilities in this transition.

Even with hybrid heat, biomethane, and hydrogen, a cost-optimal clean energy transition means contracting gas networks in Canada

Our modelling results and the results of similar studies see gas volume declining in all regions and across all sensitivities in the transition to net zero. Low-emission gases don't come close to making up the difference. Scarce supplies of biomethane and hydrogen are more optimally used to decarbonize other sectors, such as heavy industry.

Hybrid heat can be a stepping stone in many places, and part of a long-term pathway in some contexts. But those opportunities are limited, and even in cases where hybrid heat plays a larger long-term role, the gas network must likely still contract to keep costs manageable for ratepayers.

A business-as-usual approach increases the risk of higher costs, jeopardizes Canada's climate goals, or both

The longer that policymakers and regulators delay action, the greater the risk that Canadians will end up on the hook.

Under status quo utility regulation and current climate policy, greenhouse gas emissions from the buildings sector are rising, gas utilities are continuing to expand their networks, and electricity utilities are only just starting to get serious about growth.

Delayed action on the gas system will result in continued growth, adding costs that would take decades to recover. Ongoing and increasing investment in the gas system leaves remaining gas ratepayers at risk of rising gas rates, as larger numbers of gas ratepayers switch to electricity to heat their homes and businesses. It also increases the undepreciated value of assets, which can make contraction of the gas system more expensive, causing further delay.

Delayed action on the electricity side, meanwhile, risks a mismatch between growing electricity demand and supply. This can inhibit the momentum of consumers switching to electricity, which means that consumers lose out on the advantages of electrification while hampering Canada's progress to net zero.

The longer that policymakers and regulators delay action, the greater the risk that Canadians will end up on the hook for an overbuilt and underused gas system, an overburdened electrical grid, or both.

Provincial and territorial policy is the missing piece for achieving climate goals while protecting reliability and affordability

Provinces and territories oversee electric and gas utility regulation. Their policy leadership is needed to make sure Canada's energy systems and their regulators are driving the clean energy transition while protecting reliability and affordability.

Local details matter. Electricity grids and gas networks are provincially and territorially regulated; provincial economies differ; and each gas network has important spatial features. These spatial features include the extent and age of the network, and the number and type of customers connected. This challenge can therefore only be successfully navigated with detailed planning and policy leadership, province by province.

Provincial and territorial government policy attention is also required to ensure access to heating is affordable, reliable, and equitable. The clean energy transition offers opportunities to do just that. Energy efficiency, for example, can cut energy bills significantly and lastingly. But it also raises challenges. Those who would most benefit from energy efficiency and smart electrification are often the least able to afford the upfront investments required. Many households and businesses are already switching off fossil fuels, but asymmetrically across the country and across income levels. If this trend continues and only higher-income homeowners are able to retrofit homes and electrify with heat pumps, then the rising cost of maintaining the gas network could disproportionately fall on renters and lower-income Canadians.

5.2 Recommendations

While the clean energy transition will play out over several decades, the long-term implications of today's investment decisions mean that governments must start now to change the status quo and protect ratepayers from the costs of dead-end pathways. Based on our research and the conclusions above, we make the following policy recommendations.

1 Provincial governments should equip regulators, system operators, and utilities to make decisions consistent with net zero

A lack of policy clarity and alignment creates uncertainty for energy system actors. This uncertainty can delay the investments needed to deploy lower-cost and net-zero-aligned infrastructure, and risk further expansion of the gas system beyond what is cost-optimal.

In order to achieve an equitable and affordable transition, provincial governments need to clarify their policy objectives and make use of a suite of planning tools that are being deployed across a growing number of jurisdictions.

Provincial governments should:

- Legislate a target for net zero by 2050 and interim milestones, update the mandates of regulators to include achievement of these climate targets, and equip regulators with the financial and human resources needed to deliver. And in provinces where they exist, system operators and Crown utilities should receive similar mandates.

- Commission and regularly update independent, economy-wide pathway assessments, and/or leverage existing analyses that can inform development of an energy roadmap. These higher-level assessments should complement, and ideally integrate, more granular pathway assessments undertaken by utilities and/or system operators.

Produce energy roadmaps that present the government's vision for how the jurisdiction will meet its energy needs under net zero by 2050, lay out five-year milestones, and report annually on progress. In particular, roadmaps should specify the roles of the gas and electricity system through the transition and identify responsibilities for overall energy system coordination.[13]

Provincial governments can and should undertake these actions in parallel, since too much delay on any one component risks locking in dead-end pathways.

Pathway assessments and energy roadmaps should be consistent with best practices. In particular, provincial governments and regulators should consider gas and electricity systems together in related analysis and planning, so that efforts to right-size the gas system can be paired with electricity grid capital investment plans that protect energy system reliability and affordability for consumers. Such analysis and planning must be independent from any related analysis and planning by gas and electric utilities and other energy sector actors.

2 Provincial governments should stop treating gas system expansion as the default option, and equip regulators to consider alternatives

Across Canada, government policy should no longer treat the connection of new buildings to gas networks as a matter of course. In most contexts, and particularly for new developments, electric building heat should be the default, unless there is a specific local alternative such as a thermal network.

Process outcomes are currently biased in favour of gas connections in numerous and often complex ways.

13. *The organization responsible for managing this work may be an existing or new entity. Several jurisdictions have introduced new bodies to coordinate gas and electricity systems, such as the United Kingdom's Future System Operator and Massachusetts' Office of the Energy Transformation.*

To be successful, implementation of this recommendation may require provincial governments to take the following actions, many of them complementary to each other:

Provinces could immediately direct regulators to consider the risks of stranded gas assets, and compare them against alternatives to replacing and extending gas pipelines when reviewing gas utility submissions. Alternatives should be broadly defined to include electrification, efficiency measures, as well as options that could include pipes, such as thermal energy networks and waste heat recovery.

Provinces could also direct regulators to reform obligation-to-serve requirements for gas utilities, so they do not necessitate continued gas network expansion (*BDC 2024*).

Provinces could also mandate that new buildings be fully electric, except where a suitable net-zero alternative exists (such as a thermal energy network).

3 Provincial governments should require gas utilities to provide maps of their networks to facilitate a managed transition that protects ratepayers

Provincial governments, regulators, and gas utilities should start laying the groundwork for the gradual, managed contraction of gas networks.

Preparing for a smaller gas network will require balancing multiple interests, technical planning, and finding solutions to equity challenges. But the effort can pay off in savings for ratepayers.

Other jurisdictions have found that planning for declining gas demand can result in significant cost savings while better protecting the viability of remaining infrastructure (*Moore 2023*, *Energy + Environmental Economics, and ScottMadden Management Consultants 2022*). California, the Netherlands, and Germany, for example, have already begun selective, proactive gas network pruning based on detailed understanding of their gas grids. A German study found that orderly decommissioning within the country's gas grid could save up to $5 billion annually, compared to a similar pace of declining gas use, more interspersed throughout the gas network (*Herndorff et al. 2023*). Germany now mandates heat plans for all cities with more than 20,000 inhabitants (*Federal Ministry for Economic Affairs and Climate 2024*). The Netherlands has rolled out a gas-free-neighbourhood pilot in 66 communities (*OECD 2023*). In California, gas utilities are implementing targeted electrification—programs to switch customers from gas to electricity in locations that maximize benefits to the whole system—to avoid the expense and stranded asset risks of gas infrastructure replacement (*PG&E 2022*).

Mapping existing gas infrastructure is a foundational part of this proactive work. In particular, information on the age and condition of pipelines, and the anticipated timing and rate of gas pipeline replacement, is often unavailable. Requiring gas utilities to gather and share this information (in a way that protects confidentiality and security) would help provincial policymakers, regulators, and other energy utilities identify opportunities to gradually reduce the size of the gas system and address implications for rates and customer bills. Additionally, requiring utilities to share more detailed gas and electricity network information with municipalities and other utilities could help to proactively identify upcoming pipeline replacements and assess non-pipeline alternatives, such as thermal energy networks or targeted and neighbourhood-scale electrification.

4 All orders of government should strengthen policies to support building electrification, peak management, and energy efficiency

Energy efficiency and fuel switching policies differ significantly between provinces. Provinces with less experience can learn from those that have developed and implemented successful market transformation measures, such as the BC Energy Step Code.

Completing and strengthening the suite of consumer-focused policies includes:

- Regulatory certainty, including strengthened building codes for new buildings and retrofits, building performance standards, and equipment standards.
- Direct financial support for energy retrofits and smart electrification—with subsidies for low-income Canadians and financing tools for all to increase adoption rates.

- Implementation support for energy retrofits and smart electrification, such as labour market development, education and training, and community outreach initiatives.
- A broad-based, consistent, and rising price on greenhouse gas emissions.

Through their design and implementation, these policies should:

- Integrate equity objectives, including inclusion and co-design with underserved and equity-seeking groups and Indigenous communities.
- Prioritize energy efficiency and peak management. Governments and program administrators must pair electrification with efficiency to capture cost savings for the overall system and ratepayer.
- Steer investment away from dead-end pathways. An over-reliance on biomethane or hydrogen for decarbonizing buildings risks missed climate targets and high costs for ratepayers and for other sectors that must do more of the work of reducing emissions.
- Send a long-term signal to the market, via stable funding for incentive programs, clear long-term targets, and predictable improvements over time to performance-based building codes.

5 All orders of government should centre equity in policy design and provide targeted support to the most affected

Consumer-focused policy should centre equity and inclusion to ensure heating remains affordable in the clean energy transition, particularly for lower-income households.

As provincial and territorial governments and regulators take action to limit the overall size of infrastructure liabilities for all ratepayers, provincial and territorial policy must still determine who bears the remaining costs, and how. Policy choices affect how the cost of energy infrastructure is distributed within customer classes (for example, for residential ratepayers across the income spectrum), among customer classes (residential, commercial, and industrial) and across ratepayers, shareholders, and governments. Decreasing gas demand and a contracting customer base risks burdening remaining customers with high rates. Absent policy interventions, these remaining customers could be those who are least able to afford increased costs.

Governments and regulators presiding over energy system changes should anticipate equity impacts and design solutions to address them. Centring equity in policy making does not necessarily mean avoiding prudent climate and regulatory policies that could have adverse equity outcomes. Rather, it means carefully assessing the equity impacts of such policies and, where necessary, bringing in complementary, tailored policies, or supports that can address them, such as means-tested fixed charges (*Dolter and Winter 2022*) or low-income-targeted discounts on overall bills.

Regulators can play a supporting and even an implementing role in addressing equity, but need clear policy and guidance from governments to do so. It is governments that are ultimately accountable for addressing potential equity challenges.

APPENDIX 1 — THE NATEM MODEL

NATEM, a techno-economic optimization model run by ESMIA Consultants, can provide insight into the most cost-effective pathway to meet a given outcome. In this case, we set a net zero constraint for the whole economy to characterize how the buildings sector's technology mix and fuel use change over time and to evaluate how these changes may impact other sectors of the economy as they transition to net zero.

The constraint on emissions comes into effect in 2030 and increases linearly until reaching a limit of 10 megatonnes of carbon dioxide equivalent in 2050 (with an assumption that these remaining residual emissions would be offset by nature-based sources of negative emissions). The constraint is applied at a national level, requiring provinces and jurisdictions to reduce their emissions at a pace and scale that enables the country as a whole to decarbonize cost-effectively. Policies that were in effect or announced as of Spring 2023 must be met. Beyond this, no additional constraints are applied on the buildings sector, allowing the model to make technology and fuel choices that are consistent with achieving a cost-optimal pathway to net zero emissions economy-wide.

The NATEM model is well suited to this analysis because:

- **It can represent technologies in rich detail.** The model represents the Canadian economy in each region and sector, capturing the technologies and processes that enable the production (for example, refineries and power plants), transportation (for example, pipelines) and consumption (for example, furnaces and heat pumps) of energy. Each technology in the model is characterized by various parameters, including capital costs, operation and maintenance costs, efficiency, operational lifetime, and relevant operating constraints. Existing technologies can be replaced at the end of their lifetime or when cost-effective, with newer versions of the same technology (for example, replacing an old gas furnace with a new gas furnace) or swapped out for new technologies (for example, replacing an old gas furnace with a heat pump). The technological detail means we can analyze the energy transition from a bottom-up perspective and see the impacts of technology change on energy supply and demand, system-wide costs, and greenhouse gas emissions.

— **It can capture complex dynamics between sectors.** Because NATEM is a multi-sectoral model, containing all economic sectors, it can represent how change in one sector can affect other sectors. For example, it can characterize how electrification in sectors like buildings and transportation affects the full electricity supply chain in each province, from resource extraction to electricity delivery. This modelling approach means that NATEM is particularly well-suited to capturing the full dynamics of switching from one type of energy to another, for example, from fossil fuels to electricity.

— **It works to minimize cost across the economy, rather than in any single sector alone.** Optimizing costs across multiple sectors allows us to identify a pathway for building heat that does not merely externalize the costs of decarbonization to other sectors. To meet the net zero constraint, the model seeks to find the most efficient use of available clean energy resources across the whole economy.

We tested the robustness of the modelling results with sensitivity analyses and ground-truthing initial results with experts and stakeholders. We tested a variety of model input uncertainties (for example, technology costs and efficiencies, availability of fuel feedstocks) by configuring and running a series of sensitivity analyses (*see Table 2*). Throughout the modelling process, we engaged with stakeholders to collect feedback on modelling results and assumptions, and made adjustments to model inputs where possible.

Like all models, the NATEM model has limitations. NATEM's optimization does not account for the motivations of individual actors or how the dynamic responses of individual actors could influence the evolution of the energy system. NATEM captures some behavioural factors, for example by applying technological hurdle rates to account for consumer preferences for more familiar technology, but it is not an individual-agent-based model.

Also, even though NATEM uses the best data available and stakeholder-informed assumptions, significant uncertainty remains in particular around data points that rely on projections of the future, such as future technology and energy costs, energy demands, and resource availability. Sensitivity analyses can help to address but not fully eliminate this source of uncertainty. The pathways that we explore in this report should therefore be interpreted as possible ways that the energy system could, not will, cost-effectively transition under a certain set of assumptions.

Table 2 Description of sensitivity analyses run on the core modelled scenario

DESCRIPTION	MODEL PARAMETERS
Lower cost reductions, higher performance improvements of air-source and ground-source heat pumps	*Costs* Going down from 95% to 85% cost reduction in 2030 then from 75% to 65% in 2050. *Efficiency* Gradual increase of heat pump efficiency to reach a maximum of 130% by 2050.
Deep retrofits/rate of energy efficiency improvements and higher deployment of peak reduction measures	*Retrofits* Increase all retrofit-available capacities. Allow up to 30% of space heating by 2030 and 95% by 2060 for existing buildings.
Lower level of efficiency and higher peaks	*Efficiency* Immediate reduction of heat pump efficiency by 30% of calculated values, with no improvements over time. *Peak* All heat pumps winter peak efficiency set to 1 at all time. *Retrofit* Only allow 20% of the maximum potential for retrofit.
Lower clean electricity technology costs	*Costs* All costs aligned with CER assumptions since they are lower for solar, gas with carbon capture, and small modular reactors. However, for wind, our costs are already lower. Take 80% of the costs (same difference from NATEM and CER solar costs reduction).
Lower cost of H2 supply, distribution upgrades, and H2 appliances	*Costs* Supply costs: 30% cost reduction for green hydrogen technologies (biomass and electricity), 8% for autothermal reforming with carbon capture and 6% for other technologies. Appliance costs: 10% decrease in 2022 going to 50% decrease in 2050 for space heating, water heating and cooking appliances.
Higher availability of biomass feedstock supply; lower biomethane production cost	*Feedstock* 200% increase of biomass feedstock. *Costs* 30% reduced costs for biomethane production technologies by 2050.
Increase H2 blending	Increase H2 blending rate from 5% of energy content to 20% of energy content

APPENDIX 2 — REVIEW OF SIMILAR MODELLING STUDIES

Reference	Modelling approach	Key findings	Notes
Independent Canadian studies to determine optimal economy-wide pathways to net zero			
EPRI, 2021	***Model*** REGEN—a capacity expansion and dispatch optimization model integrated with end-use models of buildings, transportation, and industry sectors. ***Scenario*** A net zero constraint in 2050 is applied in each province. The federal carbon price is applied and is assumed to rise 10% per year after 2030.	— Electricity meets 76% and 73% of residential and commercial heating demand, respectively, in 2050. — Peak electricity demand increases by 51% between 2015 to 2050. — A significant amount of residual emissions remain in the buildings sector in 2050 due to continued use of gas. — Efficiency measures are critical to mitigating the increase in peak electricity demand.	Non-CO_2 greenhouse gas emissions are excluded from the analysis, meaning the solutions modelled address only 80% of Canada's greenhouse gas emissions. Low-emission fuels (biomethane and hydrogen) are excluded from the analysis so their potential role in decarbonizing sectors of the economy (including building heat) was not characterized. Thermal energy networks are excluded.
Langlois-Bertrand et al. 2021 **(IET)**	***Model*** NATEM—an economy-wide optimization model; includes electricity, buildings, transportation, industry, oil and gas, agriculture, and waste. ***Scenario*** Federal greenhouse gas targets are applied as constraints at a national level: 40% reduction from 2005 levels by 2030; Net zero by 2050.	— Electricity meets over 95% of residential and commercial total demand, in 2050. — Electricity generation increases around two-fold between 2016 and 2050. — Gas demand decreases by almost 100%. — Near zero emissions remain in the buildings sector in 2050. — Energy efficiency plays a significant role in a cost-optimal configuration of the buildings sector.	Hybrid systems are not included in the analysis.

Reference	Modelling approach	Key findings	Notes
Studies undertaken by Canadian gas utilities and associations to compare pathways to net zero			
Canadian Gas Association, 2021	**Model** Simulation; specific model or modelling framework is not described. **Scenarios** 1 Focus on adoption of gas heat pumps. 2 Focus on adoption of hybrid heating. 3 Focus on integrating hydrogen and biomethane into supply.	— Gas demand reduces by 30–56%. — Buildings sector emissions require offsets of 8–12 Mt CO_2 eq. in 2050 to meet net zero. — Require a combined volume of H2 and biomethane of approximately 500–850 petajoules in the buildings sector in 2050.	The modelling approach used here is designed to illustrate pathways and not to seek optimized solutions. Only the buildings sector is modelled; interactions with other sectors are not explored so the consequences of directing low-emission gases away from other sectors are not scoped in. Only the impact on emissions is modelled; the costs of the different pathways are not explored.
FortisBC, 2020	**Model** CanESS—a simulation model that accounts for energy supply and demand; includes electricity, buildings, transportation, and industry sectors. **Scenarios** 1 100% electrification economy-wide. 2 Moderate electrification economy-wide with a major role for low-emission gases.	— The 100% high electrification scenario results in a peak electricity demand in 2050 that is about 1.2x greater than the moderate electrification scenario. — Total energy system costs between 2020-2050 are 15% higher in the 100% high electrification scenario compared to the moderate electrification scenario. — Gas demand decreases by 60% in the high electrification scenario and stays constant in the moderate electrification scenario.	The modelling approach used here is designed to illustrate pathways and not to seek optimized solutions. The electricity required to produce low-emission gases is not accounted for.
Enbridge, 2023	**Model** Guidehouse's Low Carbon Pathways model—an integrated capacity expansion and dispatch optimization model that includes electricity, buildings, transportation, and industry sectors. **Scenarios** 1 High electrification economy-wide. 2 Moderate electrification economy-wide with a major role for low-emission gases.	— Electricity peak increases by 107% more in the high electrification scenario than in the scenario with moderate electrification/ more low-emission gas. — Total energy system costs between 2020 and 2050 are 6% higher in the high electrification scenario. — Annual energy demand for gas in buildings decreases by 88% and 49% respectively, in the high electrification and moderate electrification scenarios.	Though a cost-optimization model is used, the scenarios are very prescriptive and therefore limit the model from determining the cost-optimal technology and fuel mix in each sector. The high electrification scenario assumes higher carbon prices than the moderate electrification scenario. If the same carbon price was used, the moderate electrification scenario would cost more than the high electrification scenario (as was reported in the findings).

Reference	Modelling approach	Key findings	Notes
Independent International studies to determine optimal economy-wide pathways to net zero			
USA: An Open Energy Outlook: Decarbonization Pathways for the USA (*Venkatesh et al. 2022*)	***Model*** Temoa—an energy system optimization model used to analyze decarbonization pathways across the energy system. ***Scenario*** An economy-wide net zero by 2050 constraint is applied. Emissions are required to decline linearly starting in 2025.	— Electricity meets the majority of heating demand in the residential and commercial sectors in 2050. — Residential and commercial sectors see a shift to heat pumps for space heating. — By 2050 total electricity demand is more than double that in 2020. — Hydrogen is mainly used in the transportation and industrial sectors.	Due to computational limitations, the 50 states are aggregated into 9 regions. Many low-emission technology options for the industry sector are not included, so the potential pathways for decarbonizing this sector cannot be well characterized.
EU: Net-Zero Europe: Decarbonization pathways and socioeconomic implications (*D'Aprile et al. 2021*)	***Model*** The study uses two optimization tools: Decarbonization Pathway Optimizer (models combinations of technologies in the industry, transportation, buildings, and agriculture sectors), and the McKinsey Power model (models power and new fuels). Both tools optimize for the lowest system cost. ***Scenario*** EU greenhouse gas targets are applied as constraints: — 55% reduction from 1990 levels by 2030. — Net zero by 2050.	— The most cost-effective reductions can be achieved by retrofitting and replacing existing heating systems with more efficient technologies: in 2050, 40% of buildings use heat pumps, 33% use thermal energy networks, 15% use biomethane or hydrogen boilers, and 10% use solar thermal. — Low gas and oil prices can delay the adoption of renewable technologies if regulations do not exist to force fuel switching.	Fossil fuel prices were assumed to remain at current levels; the impact that falling oil and gas demand could have on prices in a net zero future was not considered. Due to computational complexity, EU-27 was modelled as 10 regions. The power and fuels model is only soft-linked to the end-use models of industry, transportation, buildings, and agriculture sectors. As a result, the modelling does cost-optimize across all economic sectors.
Australia: Pathways to Net Zero Emissions—An Australian Perspective on Rapid Decarbonization (*Brinsmead et al. 2023*)	***Model*** The study uses a combination of three models: GTEM which models global macroeconomic impacts, KPMG-EE which translates these impacts to the Australian economy, and AusTIMES which derives the least cost energy and emissions pathways. ***Scenario*** The carbon shadow price determined by GTEM to achieve net zero emissions is applied in AusTIMES.	— Electricity meets 85% of buildings sector energy demand in 2050. — By 2050, 70% of space heating and cooling in residential buildings is electrified. — Improving building thermal efficiency and replacing appliances with more efficient versions largely offsets the increase in electricity consumption associated with electrification.	

Reference	Modelling approach	Key findings	Notes
UK: The pathway to net zero heating in the UK (*Rosenow et al. 2020*)	*Model* UK TIMES model—a bottom-up techno-economic cost optimization tool. Covers energy demand in the residential, industrial, service, transport and agricultural sectors. *Scenario* A net zero by 2050 constraint is applied to two scenarios: 1 a conservative approach to technology availability, 2 a progressive approach to technology availability that provides the model with more flexibility when making investment decisions in the buildings sector.	— Gas is almost completely phased out of the residential sector by 2050; no new homes should be connected to the gas grid after 2025. — By 2050, 58% of space heating will be met by heat pumps. The remaining demand is met largely by a mix of thermal energy networks and thermal storage. — Retrofits reduce total space heating demand in the residential sector by 10% in 2050. — Electrification of fossil fuel heating increases peak demand.	The UK is characterized as a single region in the model.

ACKNOWLEDGMENTS

STAFF AUTHORS

Kate Harland	Research Lead
Sachi Gibson	Mitigation Research Director
Jason Dion	Senior Research Director
Nikhitha Gajudhur	Research Associate
Kathleen Mifflin	Senior Research Associate

STAFF CONTRIBUTORS

Dale Beugin	Executive Vice President
Christiana Guertin	Research Associate
Caroline Lee	former Mitigation Research Director
David Mitchell	Senior Communications Specialist

EXPERT PANELISTS

Louis Beaumier	Executive Director, Trottier Energy Institute
Annie Chaloux	Associate Professor of Applied Political Studies, University of Sherbrooke
Kathryn Harrison	Professor of Political Science, University of British Columbia
Andrew Leach	Professor of Economics and Law, University of Alberta
Corey Mattie	Advisory Council Member, Indigenous Clean Energy
Juan Moreno-Cruz	Associate Professor and Canada Research Chair, School of Environment, Enterprise and Development, University of Waterloo
Nancy Olewiler	Professor, School of Public Policy, Simon Fraser University
Maria Panezi	Associate Professor, University of New Brunswick Law
Pierre-Olivier Pineau	Professor, Chair in Energy Sector Management, HEC Montreal
Nicholas Rivers	Associate Professor, Canadian Research Chair, Climate and Energy Policy, University of Ottawa
Kwatuuma Cole Sayers	Executive Director, Clean Energy BC
Kristen van de Biezenbos	Professor of Law, California Western School of Law
Jennifer Winter	Associate Professor, Department of Economics and School of Public Policy, University of Calgary

EXTERNAL REVIEWERS AND CONTRIBUTORS

Chris Bataille	Adjunct Research Fellow, Center on Global Energy Policy at Columbia University and Adjunct Professor, Simon Fraser University
Gerry Forrest	Forkast Energy and Regulatory Consulting
James Glave	Bright Future Studio, Ltd
Brandon Ott	Utilis Consulting
Kathleen Vaillancourt	Energy Super Modelers and International Analysts (ESMIA)
Dan Woynillowicz	Polaris Strategy

PRODUCTION SUPPORT

Production manager: **Janina Stajic**
Design and visualizations by Voilà: *chezVoila.com*
Translation: **OpenText**

CREATIVE COMMONS

RECOMMENDED CITATION

Harland, Kate, Sachi Gibson, Jason Dion, Nikhitha Gajudhur, and Kathleen Mifflin. 2024. *Heat Exchange: How today's policies will drive or delay Canada's transition to clean, reliable heat for buildings*. Canadian Climate Institute. https://climateinstitute.ca/reports/building-heat/

REFERENCES

Abboud, Salim, Kevin Aschim, Brennan Bagdan, Partha Sarkar, Hongqi Yuan, Brent Scorfield, Christian Felske, Shahrzad Rahbar, and Louis Marmen. 2010. *Potential Production of Methane from Canadian Wastes*. *https://biogasassociation.ca/images/uploads/documents/2010/Potential_Production_of_Methane_from_Canadian_Wastes-ARC_FINAL_Report-Sept_23_2010.doc*

Advanced Energy United. 2023. Case Studies: *Gas Line Extension Allowances*. *https://advancedenergyunited.org/hubfs/2023%20Reports/Gas%20Line%20Extension%20Allowances%201.23.pdf*

Ambrose, Jillian. 2023. "'Hydrogen village' plan in Redcar abandoned after local opposition." *The Guardian*. December 14. *https://www.theguardian.com/enShahrzad Rahbar and Louis Marmenvironment/2023/dec/14/hydrogen-village-plan-in-redcar-abandoned-after-local-opposition*

ATCO. 2021. Fort Saskatchewan Hydrogen Blending Project. *https://gas.atco.com/content/dam/web/projects/projects-overview/fort-sask-hydrogen-blending-info-sheet-december2021.pdf*

Bagdanov, Kristen George. 2024. *Decarbonising the Obligation to Serve*. Building Decarbonization Coalition. *https://buildingdecarb.org/wp-content/uploads/FINAL_Decarbonizing-the-Obligation-to-Serve_March2024.pdf*

Bagdanov, Kristen George. 2022. *DecarbNation, Issue 2: The Future of Gas*. Building Decarbonization Coalition. *https://buildingdecarb.org/decarbnation-issue-2*

Baldwin, Sara, Dan Esposito, and Hadley Tallackson. 2022. *Assessing the Viability of Hydrogen Proposals: Considerations for State Utility Regulators and Policymakers*. Energy Innovation. *https://energyinnovation.org/wp-content/uploads/2022/04/Assessing-the-Viability-of-Hydrogen-Proposals.pdf*

Baril, Hélène. 2023. "Hydro-Québec veut faire annuler la décision de la Régie de l'énergie." *La Presse*. March 28. *https://www.lapresse.ca/affaires/2023-03-28/entente-de-bienergie-avec-energir/hydro-quebec-veut-faire-annuler-la-decision-de-la-regie-de-l-energie.php*

Bataille, Chris, David Sawyer, and Noel Melton. 2015. *Pathways to deep decarbonization in Canada*. SDSN (Sustainable Development Solutions Network) and IDDRI (Institute for Sustainable Development and International Relations). September. *https://advancedbiofuels.ca/wp-content/uploads/Deep-Decarbonization-Pathways-Project.pdf*

BC Hydro. 2024. *Power Pathway: Building B.C.'s energy future*. January. *https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/capital-plan/capital-plan-2024.pdf*

BCUC (British Columbia Utilities Commission). 2012. *Inquiry into the Offering of Products and Services in Alternative Energy Solutions and Other New initiatives*. *https://docs.bcuc.com/documents/decisions/2012/doc_33023_g-201-12_fei-aes-inquiry-report_web.pdf*

BCUC (British Columbia Utilities Commission). 2023. Decision and Order G-361-23. *https://www.ordersdecisions.bcuc.com/bcuc/decisions/en/item/522057/index.do*

BCUC (British Columbia Utilities Commission). 2024. *Decision and Order G-58-24. https://docs.bcuc.com/documents/other/2024/doc_76260_g-58-24-bch-2021irp-decision.pdf*

Beer, Mitchell. 2023. St. *Laurent North Denied. Canadian Climate Institute. https://climateinstitute.ca/publications/st-laurent-north-denied/*

Beugin, Dale, and Michael Gullo. 2022. "Clean electricity is a must-have for business—and for Canada's economic prosperity." July 21. Canadian Climate Institute. *https://climateinstitute.ca/clean-electricity-is-a-must-have-for-business/*

BCUC (British Columbia Utilities Commission). N.d. "BCUC Review of Thermal Energy Systems Regulatory Framework Guidelines - Phase 2." *https://www.bcuc.com/OurWork/ViewProceeding?applicationid=1210*

Bilich, Andy, Michael Colvin, and Timothy O'Connor. 2019. *Managing the Transition. Proactive Solutions for Stranded Gas Asset Risk in California*. Environmental Defense Fund. *https://www.edf.org/sites/default/files/documents/Managing_the_Transition_new.pdf*

Billimoria, Sherri, Leia Guccione, Mike Henchen, and Leah Louis-Prescott. 2018. *The Economics of Electrifying Buildings*. RMI (Rocky Mountain Institute). *https://rmi.org/insight/the-economics-of-electrifying-buildings/*

Bonbright, James C. 1960. *Principles of Public Utility Rates*. Regulatory Assistance Project (RAP). October. *https://www.raponline.org/knowledge-center/principles-of-public-utility-rates/*

Brehm, Kevin, Mark Dyson, Avery McEvoy, and Connor Usry. 2023. *Virtual Power Plants, Real Benefits*. RMI (Rocky Mountain Institute). January. *https://rmi.org/wp-content/uploads/dlm_uploads/2023/01/virtual_power_plants_real_benefits.pdf*

Brinsmead, Thomas S., George Verikios, Sally Cook, David Green, Taj Khandoker, Olivia Kember, Luke Reedman, Shelley Rodriguez, and Stuart Whitten. 2023. P*athways to Net Zero Emissions—An Australian Perspective on Rapid Decarbonisation. CSIRO. https://www.csiro.au/-/media/Environment/Net-zero/Reports/Technical-Report_Pathways-to-Net-Zero-Emissions.pdf*

Bronski, Peter, Mark Dyson, Matte Lehrman, James Mandel, Jesse Morris, Titiaan Palazzi, Sam Ramirez, and Hervé Touati. 2015. *The Economics of Demand Flexibility. How "Flexiwatts" Create Quantifiable Value for Customers and the Grid*. RMI (Rocky Mountain Institute). August. *https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_RMI-TheEconomicsofDemandFlexibilityFullReport.pdf*

Butler, Patrick. 2024. "New generation needed quickly, says Hydro report on electricity demand." *CBC News*. April 5. *https://www.cbc.ca/news/canada/newfoundland-labrador/report-hydro-demand-electricity-until-2034-1.7163682*

California Public Utilities Commission. 2022. *Staff Proposal on Gas Distribution Infrastructure Decommissioning Framework in Support of Climate Goals*. *https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/natural-gas/long-term-gas-planning-oir/framework-staff-proposal.pdf*

California Public Utilities Commission. 2023. Decision on phase 2 issues regarding transmission pipelines and storage. *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M520/K496/520496934.PDF*

Cameron, Laura, Vanessa Corkal, and Nichole Dusyk. 2022. *Why Government Support for Decarbonizing Oil and Gas Is a Bad Investment*. IISD (International Institute for Sustainable Development). October. *https://www.iisd.org/system/files/2022-10/bottom-line-decarbonizing-oil-gas.pdf*

Canadian Climate Institute. N.d. Indigenous Research. *https://climateinstitute.ca/indigenous-research/*

Canadian Net-Zero Emissions Accountability Act, Statues of Canada 2021, c.22. *https://laws-lois.justice.gc.ca/eng/acts/c-19.3/fulltext.html*

Cement Association of Canada. N.d. *Our roadmap to net-zero*. *https://cement.ca/sustainability/our-roadmap-to-net-zero/*

CER (Canada Energy Regulator). 2023. "Market Snapshot: Two Decades of Growth in Renewable Natural Gas in Canada." November. *https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2023/market-snapshot-two-decades-growth-renewable-natural-gas-canada.html*

CER (Canada Energy Regulator). 2021. "Market Snapshot: How the 2021 Summer Heat Dome Affected Electricity Demand in Western Canada." November. *https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2021/market-snapshot-how-the-2021-summer-heat-dome-affected-electricity-demand-in-western-canada.html*

Clean Energy Act, Statutes of Yukon 2022, c.14. *https://laws.yukon.ca/cms/images/LEGISLATION/PRINCIPAL/2022/2022-0014/2022-0014_1.pdf*

Climate Change Accountability Act, Statutes of British Columbia 2007, c.42. *https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/07042_01#part1*

Colorado General Assembly. 2021. Adopt Programs Reduce Greenhouse Gas Emissions Utilities. *https://leg.colorado.gov/bills/sb21-264*

Colorado Public Utilities Commission. 2022. "What are Clean Heat Plans?" *https://puc.colorado.gov/cleanheatplans*

Communauté métropolitaine de Montréal. 2024. "Émissions de ges : La CMM passe a l'acte pour favoriser la décarbonisation des bâtiments du grand Montréal." Press Release. April 25. *https://cmm.qc.ca/communiques/emissions-de-ges-la-cmm-passe-a-lacte-pour-favoriser-la-decarbonation-des-batiments-du-grand-montreal/*

Cosgrove, Erin. 2022. *Policy Tracker: Can a Clean Heat Standard Transition the Fossil Fuel Industry?* Northeast Efficiency Partnerships. April. *https://neep.org/blog/policy-tracker-can-clean-heat-standard-transition-fossil-fuel-industry*

Dairy Farmers of Canada. N.d. “Net Zero by 2050.” *https://dairyfarmersofcanada.ca/en/farmer-resources/net-zero-2050*

D’Aprile, Paolo, Hauke Engel, Godart van Gendt, Stefan Helmcke, Solveigh Hieronimus, Tomas Nauclér, Dickon Pinner, Daan Walter, and Maaike Witteveen. 2021. *Net-Zero Europe. Decarbonization pathways and socioeconomic implications*. McKinsey & Company. *https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/how%20the%20european%20union%20could%20achieve%20net%20zero%20emissions%20at%20net%20zero%20cost/net-zero-europe-vf.pdf*

DiGangi, Diana. 2023. “Green Mountain Power proposes energy storage for all Vermonters.” *Utility Dive*. October 10. *https://www.utilitydive.com/news/green-mountain-power-vermont-storage-grid-hardening/696180/*

Dunsky et al. 2024. *Powering Canada: A Blueprint for Success*. Canada Electricity Advisory Council. Government of Canada.

Dolter, Brett, and Jennifer Winter. 2022. *Electricity affordability and equity in Canada’s energy transition*. Canadian Climate Institute. *https://canadianclimat.wpenginepowered.com/wp-content/uploads/2022/09/Electricity-and-equity-canadas-energy-transition.pdf*

Efficiency Manitoba. 2021. “All About Ground Source Heat Pumps.” *https://efficiencymb.ca/articles/ground-source-heat-pumps/*

EIA (Energy Information Administration). 2019. “Demand-side management programs save energy and reduce peak demand.” *https://www.eia.gov/todayinenergy/detail.php?id=38872*

Electrification and Energy Transition Panel. 2023. *Ontario’s Clean Energy Opportunity*. *https://www.ontario.ca/files/2024-02/energy-eetp-ontarios-clean-energy-opportunity-en-2024-02-02.pdf*

Enbridge. 2022. “Clean hydrogen enters the Markham energy mix.” Press release. January. *https://www.enbridge.com/stories/2022/january/hydrogen-blending-project-enbridge-gas-cummins-operational-markham-ontario*

Energy + Environmental Economics, and scottmadden Management Consultants. 2022. *The Role of Gas Distribution Companies in Achieving the Commonwealth’s Climate Goals. Independent Consultant Report. Technical Analysis of Decarbonization Pathways*. March 18. *https://thefutureofgas.com/content/downloads/2022-03-21/3.18.22%20-%20Independent%20Consultant%20Report%20-%20Decarbonization%20Pathways.pdf*

Energy + Environmental Economics, Econsult Solutions Inc., and Portfolio Associates. 2021. *Philadelphia Gas Works Business Diversification Study. Identifying Opportunities for Philadelphia Gas Works to Thrive in a Lower-Carbon Future*. Philadelphia Gas Works (PGW). December. *https://www.phila.gov/media/20211207134817/PGW-Business-Diversification-Study-2021-12.pdf*

Environmental Goals and Climate Change Reduction Act, Nova Scotia 2021, c.20. *https://nslegislature.ca/sites/default/files/legc/statutes/environmental%20goals%20and%20climate%20change%20reduction.pdf*

EPRI (Electric Power Research Institute). 2021. *Canadian National Electrification Assessment*. September. *https://www.epri.com/research/products/000000003002021160*

European Climate Foundation and European Alliance to Save Energy (EU-ASE). 2022. *Building Europe's Net-Zero Future. Why the Transition to Energy Efficiency and Electrified Buildings Strengthens Europe's Economy.* March. European Climate Foundation

Eversource. n.d. Geothermal Pilot Project in Framinghham. *https://www.eversource.com/content/residential/about/transmission-distribution/projects/massachusetts-projects/geothermal-pilot-project*

Federal Ministry for Economic Affairs and Climate. 2024. "The Heat Planning Act: momentum for the local heat transition." *Energiewende direkt*. January 18.

https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2023/11/Meldung/news1.html#:~:text=The%20Heat%20Planning%20Act%20improves,cities%20by%2030%20June%202026.

Federation of Alberta Gas Co-ops Ltd. 2022. *A Handbook for Directors of Rural Gas Utilities. https://www.gldcgas.com/wp-content/uploads/2022/06/2022-Directors-Handbook.pdf*

Ferguson, Alex, and Jeremy Sager. 2022. *Cold-Climate Air Source Heat Pumps: Assessing Cost Effectiveness, Energy Savings and Greenhouse Gas Emission Reductions in Canadian Homes*. CanmetEnergy. *https://emrlibrary.gov.yk.ca/ebooks/cold-climate-air-source-heat-pumps-2022.pdf*

Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. 2015. *The Economics of Battery Energy Storage. How Multi-use, Customer-sited Batteries Deliver the Most Service and Value to Customers and the Grid*. RMI (Rocky Mountain Institute). October. *https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf*

FortisBC. 2024. Residential Hybrid Heating Early Adopter Program. *https://www.fortisbc.com/about-us/projects-planning/future-of-energy-efficiency/residential-hybrid-heating-early-adopter-program*

Fortis BC. 2023. "Management Discussion and Analysis for the Year Ended December 31, 2023." *https://www.cdn.fortisbc.com/libraries/docs/default-source/about-us-documents/fortisbc-(gas)-mda-q4-2023-d2-pa-sedar.pdf?sfvrsn=49c2fa5b_1*

Franceinfo. 2024. Hausse des tarifs du gaz au 1er juillet : « C'est essentiellement lié au fait que la consommation baisse », explique Emmanuelle Wargon. *Franceinfo. https://www.francetvinfo.fr/economie/energie/hausse-des-tarifs-du-gaz-au-1er-juillet-c-est-essentiellement-lie-au-fait-que-la-consommation-baisse-explique-emmanuelle-wargon_6344641.html*

Fransen, Aaron, Lanetter Wilkinson, Tara Watson, Parker Mckibbon, and Kyle Hatton. 2024. *Legislative, Procurement and Governmental Updates Signal that British Columbia is Ripe for Renewable Energy Development*. Stikeman Elliott. *https://www.stikeman.com/en-ca/kh/canadian-energy-law/british-columbia-is-ripe-for-renewable-energy-development*

Gattaciecca, Julien, Kelly Trumbull, Samuel Krumholz, Kelley McKanna, and J.R. DeShazo. 2020. *Identifying Effective Demand Response Program Designs for Residential Customers*. California Energy Commission. November. *https://innovation.luskin.ucla.edu/wp-content/uploads/2021/01/Identifying-Effective-Demand-Response-Program-Designs-for-Residential-Customers.pdf*

Glave, James, and Robyn Wark. 2019. *Lessons From the BC Energy Step Code*. *https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/reports/bcenergystepcode_lessons_learned_final.pdf*

Government of Alberta. 2023. *Alberta emissions reduction and energy development plan*. January 2024. *https://open.alberta.ca/dataset/7483e660-cd1a-4ded-a09d-82112c2fc6e7/resource/75eec73f-8ba9-40cc-b7f4-cdf335a1bd30/download/epa-emissions-reduction-and-energy-development-plan.pdf*

Government of British Columbia. 2024. “BC Hydro issues call for new clean electricity to power B.C.’s future.” *Energy, Mines and Low Carbon Innovation*. Press release. *https://news.gov.bc.ca/releases/2024EMLI0018-000470*

Government of British Columbia. 2022. “Province hits pause on electrical connections for cryptocurrency mining.” *Energy, Mines and Low Carbon Innovation*. Press release. December 21. *https://news.gov.bc.ca/releases/2022EMLI0067-001928*

Government of British Columbia. 2015. Climate Change. Long-term Change in Energy Requirements for Heating & Cooling Buildings in B.C. *https://www.env.gov.bc.ca/soe/indicators/climate-change/heating-cooling-days.html*

Government of Manitoba. N.d. Made-in-Manitoba Climate and Green Plan. *https://www.gov.mb.ca/climateandgreenplan/index.html*

Government of New Brunswick. 2022. “Updated climate change action plan released.” Press release. *https://www2.gnb.ca/content/gnb/en/news/news_release.2022.09.0508.html*

Government of Nova Scotia. 2024. ”Statement on Report from Clean Electricity Solutions Task Force” Press release. February 23. *https://news.novascotia.ca/en/2024/02/23/statement-report-clean-electricity-solutions-task-force*

Government of Ontario. 2023. *Powering Ontario’s Growth: Ontario’s Plan for a Clean Energy Future*. *https://www.ontario.ca/files/2023-07/energy-powering-ontarios-growth-report-en-2023-07-07.pdf*

Government of Ontario. 2021. Phase 2 of the Natural Gas Expansion Program. Environmental Registry of Ontario. *https://ero.ontario.ca/notice/019-3191*

Government of Ontario. 2019. Natural Gas Expansion Program. Ministry of Energy. January 25, 2023. *https://www.ontario.ca/page/natural-gas-expansion-program*

Government of Prince Edward Island. 2024. Path to Net Zero. *https://www.princeedwardisland.ca/en/information/environment-energy-and-climate-action/path-to-net-zero*

Government of Québec. 2023a. Plan’s numerical targets. May 17. *https://www.quebec.ca/en/government/policies-orientations/plan-green-economy/implementation/plans-numerical-targets*

Government of Québec. 2023b. Procedure for obtaining connection authorization for projects with power ratings of 5 MW or more. Ministère de l’Économie, de l’Innovation et de l’Énergie. December 27. *https://www.economie.gouv.qc.ca/en/outside-quebec/procedure-obtain-authorization-connect-project-power-5-mw-or-more*

Graves, Frank, Josh Figueroa, Long Lam, Kasparas Spokas, Tess Counts, Maria Castaner, Katie Mansur, and Shreeansh Agrawal. August 2021. The Future of Gas Utilities Series: Transitioning Gas Utilities to a Decarbonized Future. Part 1 of 3. Brattle. August. *https://www.brattle.com/wp-content/uploads/2022/01/The-Future-of-Gas-Utilities-Series__Part-1.pdf*

Gridworks. 2021. *Gas Resource and Infrastructure Planning for California. A Proposed Approach to Long-Term Gas Planning*. Gridworks. January. *https://gridworks.org/wp-content/uploads/2021/01/CA_Gas_Resource_Infrastructure_Plan_Report_FINAL.pdf*

Guidehouse. 2022. *Decarbonisation pathways for the European building sector.* ehi (European Heating Industry). July. *https://ehi.eu/wp-content/uploads/2022/10/Decarbonisation-pathways-for-the-EU-building-sector_full-study-1.pdf*

Harland, Kate. 2024. "Change is in the pipeline—will expanding gas networks leave ratepayers on the hook?." *Canadian Climate Institute*. March. *https://climateinstitute.ca/energy-boards-transition-gas/*

Herrndorff, Mareike, Anna Kraus, Simon Müller, Dr. Barbara Saerbeck, Uta Weiß, Ralph Kremp, Stefan Mischinger, Dr. Andreas Nolde, Oliver Radtke, Dr. Konstantina Bourazeri, Wiegand Laubenstein, Jana Michaelis, and Dr. Peter Rosin. 2022. *Ein neuer Ordnungsrahmen für Erdgasverteilnetze.* Agora Energiewende. *https://static.agora-energiewende.de/fileadmin/Projekte/2022/2022-06_DE_Gasverteilnetze/A-EW_291_Gasverteilnetze_WEB.pdf*

Hydro Québec. 2023. *Towards a Decarbonized and Prosperous Quebec. Action Plan 2035*. Hydro Québec. November. *https://www.hydroquebec.com/data/a-propos/pdf/action-plan-2035.pdf*

IEA (International Energy Agency). 2023a. *World Energy Outlook 2023*. IEA Paris. *https://www.iea.org/reports/world-energy-outlook-2023*

IEA (International Energy Agency). 2023b. *Comparison of the emissions intensity of different hydrogen production routes, 2021*. IEA Paris. *https://www.iea.org/data-and-statistics/charts/comparison-of-the-emissions-intensity-of-different-hydrogen-production-routes-2021*

IEA (International Energy Agency). 2021. *Net Zero by 2050*. IEA Paris. *https://www.iea.org/reports/net-zero-by-2050*

IEA (International Energy Agency). 2020. *Outlook for biogas and biomethane: Prospects for organic growth*. IEA Paris. *https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth*

IRENA (International Renewable Energy Agency). 2019. *Aggregators: Innovation Landscape Brief. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Aggregators_2019.PDF*

Kanduth, Anna. 2023. "How hot are heat pumps, really?" *Canadian Climate Institute*. November 22. *https://440megatonnes.ca/insight/how-hot-are-heat-pumps-really/*

Kelleher Environmental. 2013. *Canadian Biogas Study: Benefits to the Economy, Environment and Energy*. Canadian Biogas Association. *https://biogasassociation.ca/images/uploads/documents/2014/biogas_study/Canadian_Biogas_Study_Summary.pdf*

Kemfert, Claudia, Fabian Präger, Isabell Braunger, Franziska M. Hoffart, and Hanna Brauers. 2022. "The expansion of natural gas infrastructure puts energy transitions at risk." *Nature Energy, Springer Nature*, Berlin, Vol. 7, pp. 582-587. *https://doi.org/10.1038/s41560-022-01060-3*

Labbé, Stefan. 2023. "FortisBC's plan to keep burning gas 'not equitable,' claims B.C. city." *Business Intelligence for B.C*. August. *https://www.biv.com/news/environment/fortisbcs-plan-keep-burning-gas-not-equitable-claims-bc-city-8272851*

Langevin, Jared, Aven Satre-Meloy, Andrew J. Satchwell, Ryan Hledik, Julia Olszewski, Kate Peters, and Handi Chandra-Putra. 2023. "Demand-side solutions in the US building sector could achieve deep emissions reductions and avoid over $100 billion in power sector costs." *One Earth 6(8): 1005-31*. doi:10.1016/j.oneear.2023.07.008

Langlois-Bertrand, Simon, Normand Mousseau, Louis Beaumier, and Olivier Bahn. 2021. *Canadian Energy Outlook*. Institut de l'énergie Trottier (IET). *https://iet.polymtl.ca/wp-content/uploads/delightful-downloads/CEO2021_20211008-1.pdf*

Le Devoir. 2023. "Énergir conteste un règlement de Prévost sur la décarbonation des bâtiments." *Le Devoir*. November. *https://www.ledevoir.com/societe/justice/801965/energir-conteste-reglement-prevost-decarbonation-batiments?utm_source=ground.news&utm_medium=referral*

Lee, Caroline, Jason Dion, and Christiana Guertin. 2022. *Bigger, Cleaner, Smarter: Pathways for aligning Canadian electricity systems with net zero*. Canadian Climate Institute. *https://climateinstitute.ca/wp-content/uploads/2022/05/Bigger-Cleaner-Smarter-May-4-2022.pdf*

LEI (London Economics International). 2023. *Recommendation for appropriate capital structure for Enbridge Gas in its application for 2024 rebasing and 2025-2028 price cap plan. https://www.rds.oeb.ca/CMWebDrawer/Record/785972/File/document*

Linden-Fraser, Ross. 2024. "Are the provinces and territories holding themselves accountable for climate action?" *Canadian Climate Institute*. January 15. *https://440megatonnes.ca/insight/are-the-provinces-and-territories-holding-themselves-accountable-for-climate-action/*

Linden-Fraser, Ross. 2023. "A closer look at the varying climate targets of the provinces and territories." *Canadian Climate Institute*. October. *https://440megatonnes.ca/insight/closer-look-varying-climate-targets-provinces-territories/*

Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, and Snuller Price. 2018. *Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model*. California Energy Commission. Publication Number: CEC-500-2018-012

Martin, Liza, and Kevin Brehm. 2023. "Clean Energy 101: Virtual Power Plants." *RMI (Rocky Mountain Institute)*. January 10. *https://rmi.org/clean-energy-101-virtual-power-plants/*

Massachusetts Department of Public Utilities. 2023. D.P.U. 20-80-B. December 6. *https://www.clf.org/wp-content/uploads/2023/12/DPU-20-80-B-Order-12.6.2313.pdf*

McClearn, Matthew. 2022. "As calls grow for a doubling or tripling of Canada's electricity generation capacity, some utilities have other ideas." *The Globe and Mail*. October 18. *https://www.theglobeandmail.com/business/article-canada-electricity-expansion/*

McDiarmid, Heather. 2022a. *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps. Ontario Clean Air Alliance Research*. August 2. *https://www.cleanairalliance.org/wp-content/uploads/2022/08/Heat-Pump-Report-gas-heated-2022-8.5x11-aug-02-v_01.pdf*

McDiarmid, Heater. 2022b. *An Analysis of the Financial and Climate Benefits of Using Ground-Source Heat Pumps to Electrify Ontario's Gas-Heated Homes*. Ontario Clean Air Alliance Research. November 10. *https://www.cleanairalliance.org/wp-content/uploads/2022/11/GSHP-final-report.pdf*

Mertz, Emily. 2021. Alberta eclipses previous summer peak electricity use record Monday. Global News. June 28. *https://globalnews.ca/news/7988330/alberta-electricity-use-record-heat-wave/*

Mihaly, Elena. 2023. "Vermont Affordable Heat Act: What Comes Next." *Conservation Law Foundation (clf)*. October. *https://www.clf.org/blog/vermont-affordable-heat-act-what-comes-next/#:~:text=The%20law%20will%20require%20companies,heat%20credits%20it%20must%20earn.*

Miller, Sarah, Kate Harland, Christiana Guertin, and Ricardo Pelai. September 2023. *Heat Pumps Pay Off.* Canadian Climate Institute. *https://climateinstitute.ca/reports/heat-pumps-canada/*

Moore, Emily. 2023. *It's time for Cascadia to start pruning the gas system and electrifying whole neighborhoods*. Sightline Institute. *https://www.sightline.org/2023/06/07/its-time-for-cascadia-to-start-pruning-the-gas-system-and-electrifying-whole-neighborhoods/*

Nadel, Steven. February 9, 2017. "Demand response programs can reduce utilities' peak demand an average of 10%, complementing savings from energy efficiency programs." *ACEE*. *https://www.aceee.org/blog/2017/02/demand-response-programs-can-reduce*

Nelson, Ron, Bradley Cebulko, Thomas Van Hentenryck, Erin Mettler, and Natalie Mims Frick. 2023. *Non-Pipeline Alternatives: A Regulatory Framework and a Case Study of Colorado*. Lawrence Berkeley National Laboratory. *https://eta-publications.lbl.gov/sites/default/files/non-pipeline_alternatives_to_natural_gas_utility_infrastructure_2_final.pdf*

Net Zero Carbon Act, *Prince Edward Island*, *2021, c3.01*. *https://www.princeedwardisland.ca/sites/default/files/legislation/n-03-01-net-zero_carbon_act.pdf*

Net Zero Tracker. 2022. Net Zero Stocktake 2022. June 12. *https://zerotracker.net/insights/pr-net-zero-stocktake-2022*

Nova Scotia Power. N.d. Investing in our future: Battery storage pilot program. *https://www.nspower.ca/cleanandgreen/innovation/smart-grid-nova-scotia/battery-pilot*

NRCan (Natural Resources Canada). 2023a. 2019 Survey of Commercial and Institutional Energy Use (SCIEU)—Buildings—Data Tables [Table 8.1]. *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTablecfm?type=SC&sector=aaa&juris=ca&year=2019&rn=13&page=1*

NRCan (Natural Resources Canada). 2023b. 2019 Survey of Commercial and Institutional Energy Use (SCIEU)—Buildings—Data Tables [Table 8.2]. *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=SC&sector=aaa&juris=ca&year=2019&rn=14&page=1*

NRCan (Natural Resources Canada). 2022. Heating and Cooling with a Heat Pump. *https://natural-resources.canada.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817*

NRCan (Natural Resources Canada). 2020. Comprehensive Energy Use Database. Residential Sector. [Table 27]. *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTablecfm?type=CP&sector=res&juris=ca&year=2020&rn=27&page=0*

NRCan (Natural Resources Canada). n.d. Comprehensive Energy Use Database. Residential Sector. [Table 2]. *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=res&juris=ca&year=2021&rn=2&page=0*

NSUARB (Nova Scotia Utility and Review Board). 2023. Decision 2023 NSUARB 166 M10960. *https://nsuarb.novascotia.ca/sites/default/files/NSUARB%20Board%20Decision%20-%20Eastward%20Energy%20Inc%20-%20Natural%20Gas%20-%20M10960%20Decision.pdf*

NYSERDA (New York State Energy Research and Development Authority). 2022. *The Future of Buildings: New York's Carbon Neutral Buildings Roadmap.* December. *https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Carbon-Neutral-Buildings/Roadmap-executive-summary.pdf*

NZAB (Net-Zero Advisory Body). 2020. *Net-Zero Pathways: 10 values and principles.* *https://www.nzab2050.ca/publication-report/net-zero-pathways-10-values-and-principles*

OEB (Ontario Energy Board). 2023. Decision and Order EB-2022-0200. *https://www.rds.oeb.ca/CMWebDrawer/Record/827754/File/document*

OEB (Ontario Energy Board) 2021. Decision and Order 2020-0091. *decision and order - eb-2020-0091 enbridge gas inc.Ontario Energy Boardhttps://www.rds.oeb.ca › Record › File › document*

OEB (Ontario Energy Board). 2009. Decision EB-2009-0172. *https://www.oeb.ca/oeb/_Documents/Decisions/dec_EGDI_preliminary_motion_20091222.pdf*

OECD. 2023. *Decarbonising Homes in Cities in the Netherlands: A Neighbourhood Approach.* *https://www.oecd.org/publications/decarbonising-homes-in-cities-in-the-netherlands-b94727de-en.htm*

Ofgem. 2023. Page 70. *RIIO-3 Sector Specific Methodology Consultation—Finance Annex*. December. *https://www.ofgem.gov.uk/sites/default/files/2023-12/RIIO-3%20SSMC%20Finance%20Annex.pdf*

PG&E. 2022. "Amended Application of Pacific Gas and Electric Company (U 39 G) for Approval of Zonal Electrification Pilot Project." Public Utilities Commission of the State of California. December. *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M500/K435/500435462.PDF*

RMI (Rocky Mountain Institute). 2022. Email: Re: Investigation into the Role of the Gas Local Distribution Companies as the Commonwealth Achieves its 2050 Climate Goals, D.P.U. 20-80 *https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/14923028*

Rosenow, Jan, Richard Lowes, Oliver Broad, Graeme Hawker, Jianzhong Wu, Meysam Qadrdan, and Robert Gross. 2020. *The pathway to net zero heating in the UK*. UKERC (UK Energy Research Centre). October. doi:10.5286/ukerc.edc.000941

Samson, Rachel, Jonathan Arnold, Weseem Ahmen, and Dale Beugin. 2021. *Sink or Swim. Transforming Canada's economy for a global low-carbon future*. Canadian Climate Institute. October. *https://climatechoices.ca/wp-content/uploads/2021/10/CICC-Sink-or-Swim-English-Final-High-Res.pdf*

Sawyer, Dave, Anna Kanduth, Bradford Griffin, Franziska Förg, Ross Linden-Fraser, and Arthur Zhang. 2023. *Independent Assessment of Canada's 2023 Emissions Reduction Plan Progress Report*. Canadian Climate Institute. *https://climateinstitute.ca/wp-content/uploads/2023/12/ERP-assessment-2023-EN-FINAL.pdf*

Séguin, Hugo, and Alex Bigouret. 2023. *Hybrid heat in Quebec: Energir and Hydro-Quebec's collaboration on building heat decarbonization*. Canadian Climate Institute. *https://climateinstitute.ca/publications/hybrid-heat-in-quebec/*

Sokic, Nicholas. 2023. "Énergir pledges 100% renewable energy for new grid hookups." *Sustainable Biz Canada*. April. *https://sustainablebiz.ca/energir-commits-to-100-renewable-energy-for-new-grid-connections*

Specian, Mike, Charlotte Cohn, and Dan York. 2021. *Demand-Side Solutions to Winter Peaks and Constraints*. ACEE. *https://www.aceee.org/research-report/u2101*

Statistics Canada. 2023. Canadian Social Survey: Energy Use. *https://www150.statcan.gc.ca/n1/daily-quotidien/231030/dq231030b-eng.htm*

Stephen, Jamie, M. Jean Blair, Liz Brennan, and Susan Wood-Bohm. 2020. *Renewable Natural Gas (Biomethane) Feedstock Potential in Canada*. Torchlight Bioresources. *https://www.enbridge.com/~/media/Enb/Documents/Media%20Center/RNG-Canadian-Feedstock-Potential-2020%20(1).pdf*

Stiebert, Seton, and Dave Sawyer. 2023. "Emissions from oil and gas, buildings undercut Canada's climate progress." Canadian Climate Institute. *https://440megatonnes.ca/insight/emissions-oil-and-gas-buildings-undercut-canadas-climate-progress/*

Sullivan, Magdalen, and Erin Murphy. 2024. *Non-Pipeline Alternatives: Meeting Energy Demand Responsibly*. Environmental Defense Fund. February. *https://www.edf.org/sites/default/files/2024-02/Non-Pipeline-Alternatives-Report_EDF_Feb2024.pdf*

The Canadian Press. 2023. "Energy minister may accept less than half of projects over Hydro concerns." *CTV News*. January 31. *https://montreal.ctvnews.ca/energy-minister-may-accept-less-than-half-of-projects-over-hydro-concerns-1.6253564*

Topolski, Kevin, Evan P. Reznicek, Burcin Cakir Erdener, Chris W. San Marchi, Joseph A. Ronevich, Lisa Fring, Kevin Simmons, Omar Jose Guerra Fernandez, Bri-Mathias Hodge, and Mark Chung. 2022. *Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology*. NREL (National Renewable Energy Lab). *https://www.nrel.gov/docs/fy23osti/81704.pdf*

Turner, Chris. 2023. "Heat pumps are hot in the Maritimes". *Canadian Climate Institute*. April. *https://climateinstitute.ca/publications/heat-pumps-are-hot-in-the-maritimes/#:~:text=The%20rise%20of%20the%20Maritimes%20anomaly%20in%20heat%20pump%20adoption,of%20all%20New%20Brunswick%20residences.*

Utilis Consulting. 2023. *Back to Bonbright: Economic Regulation Fundamentals can Enable Net Zero*. Electricity Canada. *https://issuu.com/canadianelectricityassociation/docs/ec_sel_frame_-_2023_21_*

Utilities Commission Act, British Columbia 1996, c.473. *https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96473_01#section28*

Venkatesh, Aranya, Katherine Jordan, Aditya Sinha, Jeremiah Johnson, and Paulina Jaramillo. 2022. *Open Energy Outlook: Decarbonization Pathways for the USA*. Wilton E. Scott Institute for Energy Innovation. *https://www.cmu.edu/energy/key-initiatives/open-energy-outlook/oeo-report-2022.html*

Vermont Public Utility Commission. 2023. Clean Heat Standard. *https://puc.vermont.gov/clean-heat-standard*

Williams, James H., Ryan A. Jones, Ben Haley, Gabe Kwok, Jeremy Hargreaves, Jamil Farbes, and Margaret S. Tom. 2021. “Carbon-Neutral Pathways for the United States.” *AGU Advances 2(1)* (January). doi: 10.1029/2020AV000284

Yoo, Yeong, Hirem Bara, Nancy Glass, and Ryan Baker. 2022. *H2 blending into the Canadian NG grid network and H2 tolerances in end-use appliances*. March 31. NRCan (Natural Resources Canada). *doi.org/10.4224/23002611*

HEAT EXCHANGE

How today's policies will drive or delay
Canada's transition to clean,
reliable **heat for buildings**

CANADIAN CLIMATE INSTITUTE
L'INSTITUT CLIMATIQUE DU CANADA

This is **Exhibit C** referred to in the affidavit of Susan Brandum sworn or affirmed before me on July 25, 2025.

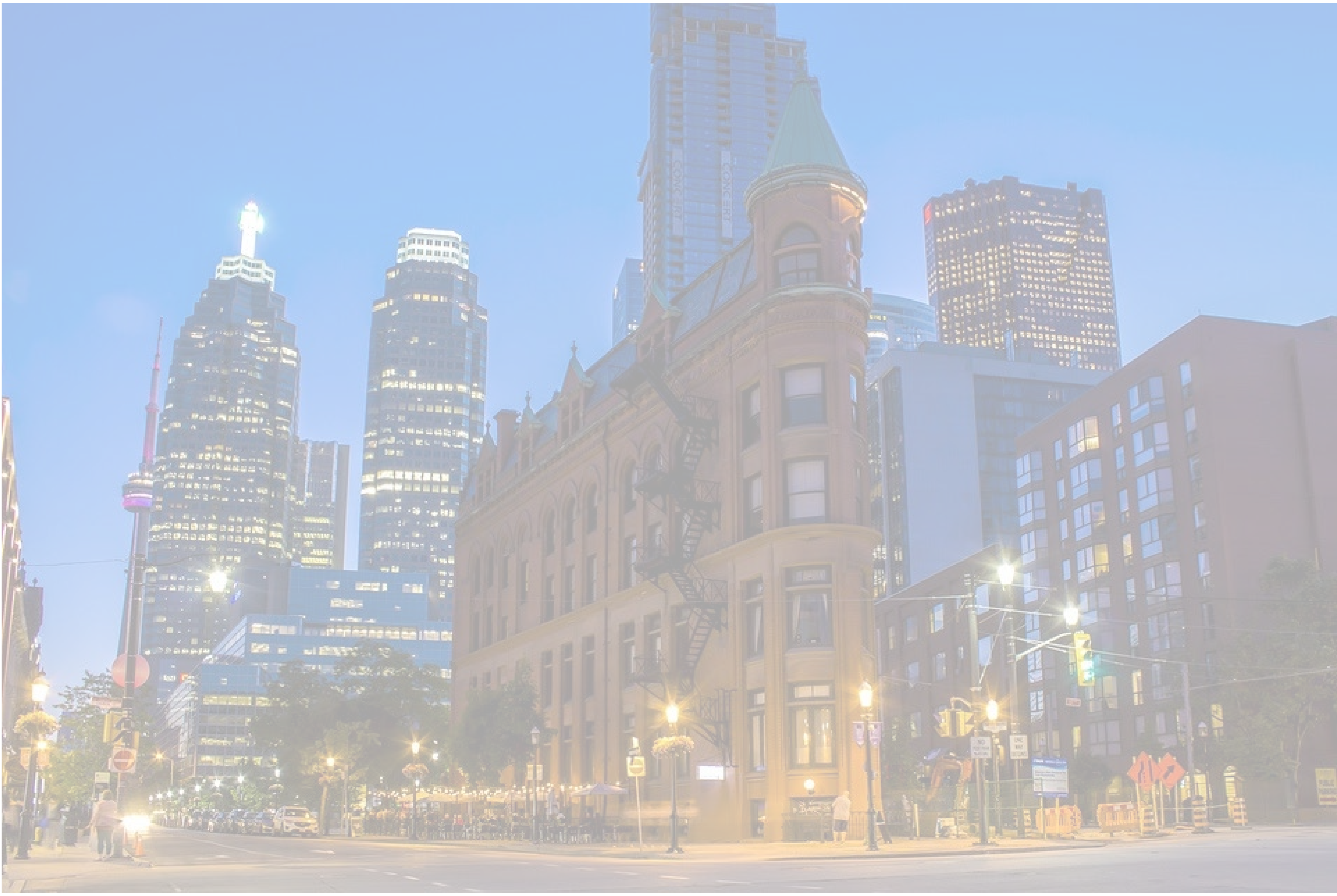
____
Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C

August 2024

Cost Effective Energy Pathways Study for Ontario

Deliverable 9 – Final Report

For Ontario Ministry of Energy and Electrification (Canada)



ESMIA Energy Super Modelers and International Analysts

dunsky Energy + Climate

The Ministry of Energy and Mines made minor changes to this report received from ESMIA and Dunsky Energy + Climate Advisors to link to data tables, posted on the Ontario Data Catalogue for accessibility: https://data.ontario.ca/dataset/data-tables-for-cost-effective-energy-pathways-study-final-report.

About ESMIA

ESMIA offers a solid expertise in 3E (energy-economy-environment) integrated system modelling for strategic decision-making at city, regional, national and global scales. We specialize in economy-wide energy system optimization models. We have participated in the development of turnkey large scale energy system models using a large variety of platforms. Many high-profile public and private organizations worldwide have called upon our expertise, in both developed and developing countries. Additionally, we offer advisory services using our proprietary models that focus on analyzing complex and long-term problems such as energy security, electrification, energy transitions, and climate change mitigation.

About Dunsky

Dunsky Energy + Climate Advisors supports leading governments, utilities, corporations and non-profits across North America in their efforts to accelerate the clean energy transition, effectively and responsibly. Founded in 2004, Dunsky assesses, designs, and evaluates clients' decarbonization strategies, programs, and plans, drawing on our deep expertise across technologies, industry practices, and innovative market strategies across Canada and the United States. Our expertise is focused primarily on buildings/industry, energy, and mobility. Our work covers all market sectors and segments, as well as innovative and cross-cutting (enabling) strategies.

Table of Contents

Table of Figures

List of Abbreviations

ACC	Abatement Cost Curve
ASHP	Air-Source Heat Pump
BECCS	Bioenergy with Carbon Capture and Storage
BEV	Battery Electric Vehicle
CAT	Catenary System
CBA	Carbon Border Adjustment
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CER	Clean Electricity Regulations
CFR	Clean Fuel Regulations
DAC	Direct Air Capture
DES	District Energy System
DER	Distributed Energy Resources
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSHP	Ground-Source Heat Pump
HD	Heavy-Duty
ICE / ICEV	Internal Combustions Engine Vehicles
IP	Integrated Pathway
ITC	Investment Tax Credit
LDES	Long-Duration Energy Storage
NET	Negative Emission technology
NIR	National Inventory Report
NZ	Net-zero

OER	Ontario Electricity Rebate
PHEV	Plug-In Hybrid Vehicle
PRC	Project Review Committee
RNG	Renewable Natural Gas
RPP	Refined Petroleum Products
SA	Sensitivity Analysis
SC-CH4	Social Cost of Methane
SC-CO2	Social Cost of Carbon Dioxide
SC-GHG	Social Cost of Greenhouse Gas
SC-N2O	Social Cost of Nitrous Oxide
SMR	Small Modular Nuclear Reactor
T&D	Transmission and Distribution
ZEV	Zero Emission Vehicle

For a list of abbreviations of integrated pathways and sensitivity analyses, see Table 1-1 and Appendix B.

List of Units

B$ CAD2022	Billion real Canadian 2022 dollars
B$ CAD2022/y	Billion real Canadian 2022 dollars per year
CAD2022	Real 2022 Canadian dollars
CAD2022/y	Real 2022 Canadian dollars per year
GJ/m^2	Gigajoules (10^9 joules) per square meter
GW	Gigawatts (10^9 watts)
GWh	Gigawatt-hours (10^9 watt-hours)
GWh/y	Gigawatt-hours (10^9 watt-hours) per year
M$ CAD2022	Million real Canadian 2022 dollars
M$ CAD2022 (2019 to X)	Cumulative million real Canadian 2022 dollars from 2019 to year X
M$ CAD2022/y	Million real Canadian 2022 dollars per year
Mt CO2eq	Million tonnes of carbon dioxide equivalent
Mt CO2eq/y	Million tonnes of carbon dioxide equivalent per year
MW	Megawatt (10^6 watts)
pkm	Passenger kilometers
TJ	Terajoules (10^{12} joules)
TJ/y	Terajoules (10^{12} joules) per year
tkm	Tonne kilometers
TWh	Terawatt-hours (10^{12} watt-hours)
TWh/y	Terawatt-hours (10^{12} watt-hours) per year

SUMMARY

Executive Summary

Study context

ESMIA Consultants, in collaboration with Dunsky Energy + Climate Advisors, has been commissioned by the Ontario Ministry of Energy and Electrification to conduct an independent Cost-Effective Energy Pathways Study that identifies least-cost pathways to decarbonizing the province's energy system by 2050.

This report, as one of the final outcomes of the Study, consolidates and summarises the key insights from the research, modelling and analysis conducted to provide insights to decision-makers, stakeholders, and communities (including Indigenous communities) on where Ontario is today, pathways for decarbonizing Ontario's energy system, the potential impacts of and barriers to these pathways, and key solutions to ensure that Ontario seizes the opportunity of the energy transition and secures a prosperous, competitive, net-zero future.

Ontario is making progress and is positioned for success in the global energy transition

The global energy transition is well underway, driven by declining clean technology costs, increasing demand for energy services, and ambitious policy commitments. For Ontario, transitioning to a net-zero economy offers benefits such as attracting investment, creating skilled jobs, and driving innovation in clean technologies. Failure to act beyond 2030 to achieve climate goals could impact Ontario's competitiveness, increase costs of the transition, and lead to significant environmental and health damages.

Ontario has experienced economic growth with stable energy consumption and declining GHG emissions over the past decade. Key milestones include the phase-out of coal-fired electricity generation in the province, as well as a significant increase in solar and wind capacity, which has quadrupled since 2010. Despite these positive trends, achieving net-zero by 2050 will require further significant reductions across all sectors.

Achieving net-zero by 2050 in the different pathways will involve integrating new fuels and technologies, each with associated costs and uncertainties. Key fuels and technologies will vary by sector. Nuclear, particularly small modular reactors (SMRs), as well as onshore wind and long-duration energy storage (LDES) will play key roles in decarbonizing and growing electricity generation; while electrification of space heating and water heating will be crucial to decarbonizing the province's buildings sector.

A major energy system transition is required to reach net-zero

The study leverages three sophisticated models: an energy systems optimization model, a rate impacts model, and a macroeconomic model (NATEM, RateVision, and NAGEM)[1]. Multiple integrated pathways (IPs) are modelled to identify least-cost pathways for Ontario's energy future, including a **Reference Case** (REF IP) business-as-usual trajectory that includes committed policies; ten **Net-Zero Integrated Pathways** (NZ IPs) with a net-zero GHG emissions constraints in 2050; and eight **Sensitivity Analyses** (SAs) that capture the impact of key uncertainties around the pace of cost declines and availability of new technologies. Results from this study should not be interpreted as forecasts or most likely outcomes, but rather represent least-cost optimal solutions.[2]

Across NZ IPs, four key pillars are needed to enable a least-cost pathway for Ontario to achieve net-zero in 2050.

- **REDUCING** total final energy consumption, e.g., by 31% in the NZ50 IP in 2050 (compared to 2019) (Figure ES-1);
- **SWITCHING** more than 80% of fossil fuel use to emission-free electricity, with targeted use of clean fuels from 2019 to 2050;

Electrification of end-uses in the transportation, buildings and industrial sectors is a key enabler of this transition, and total demand for electricity is expected to increase to 2-3x across NZ IPs, to 320-467 TWh/y.

- **GROWING** electricity generation capacity, e.g. to over 2x from 2019 to 2050 in NZ50, primarily through new additions of wind, nuclear (mainly SMRs), energy storage and solar, and growing the associated transmission and distribution capacity.

Ontario's electricity supply will need to expand significantly – on the order of to double to triple today's system across all NZ IPs– to power the province's economy. In 2050, 87-115 GW of installed capacity will be needed to meet the province's electricity demand in the NZ IPs, (e.g. Figure 5-8 shows the NZ50 IP). The growth in electricity supply in NZ IPs is largely dominated by growth in wind and nuclear capacity, 12-26 GW and 12-31 GW respectively, between 2019 and 2050, as well as rooftop PV and storage. Significant investment will be required to support growth of capacity and transmission and distribution infrastructure.

- **SEQUESTERING** remaining GHG emissions (e.g., 20 Mt CO2 per year in the NZ50 IP in 2050) using CCS and DAC, and (~12Mt CO2eq per year in the NZ50 IP in 2050) using NETs.

[1] NATEM, NAGEM, and RateVision are developed and operated by ESMIA (www.esmia.ca)

[2] For example, the modelling has limited consideration of market barriers and economically irrational decisions and does not represent the behavior of individual economic agents or consumers.

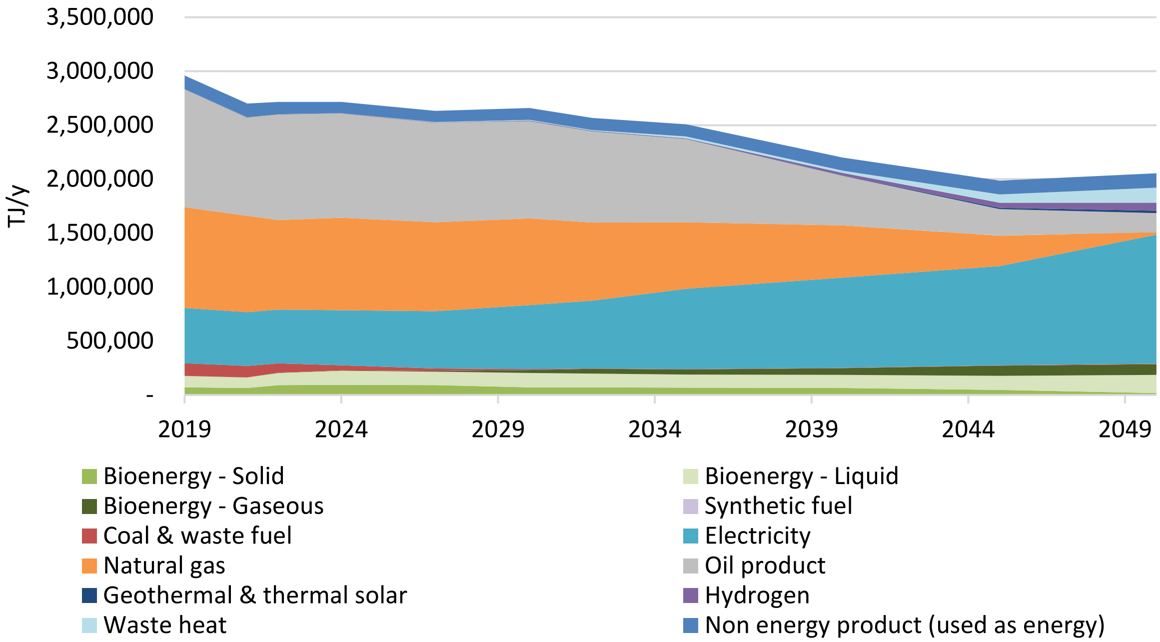


Figure ES-1. Final energy consumption (TJ/y) by fuel type from 2019 to 2050 for the NZ50 IP

Despite the directional alignment of these four pillars across the modeled integrated pathways, the results also highlight specific nuanced considerations and uncertainties around: the role of clean fuels, the magnitude of electricity growth, the trade-offs between the magnitude of wind and nuclear deployment, and the potential of CCS and negative emissions. Future government policies, innovations, and climate impacts (not modelled) are also key uncertainties.

Significant action and investments are required to reach net-zero

Achieving net-zero in 2050 will require significant action. In the least-cost REF pathway, Ontario would reach its 2030 greenhouse gas (GHG) emissions target if all assumed policies and actions materialize. However, business-as-usual policies, including committed policies (in the REF pathway), fall short of net-zero in 2050.

To close the gap and achieve net-zero GHG emissions in 2050, there is a need for significant emissions reductions across all sectors in the NZ IPs: residential and commercial sector emissions are completely eliminated in 2050; transportation sector emissions are reduced by 90% (compared to 2019); industrial and electricity sectors become net-negative emitters, through carbon capture and storage (CCS) and negative emissions technologies (NETs) (Figure ES-2).

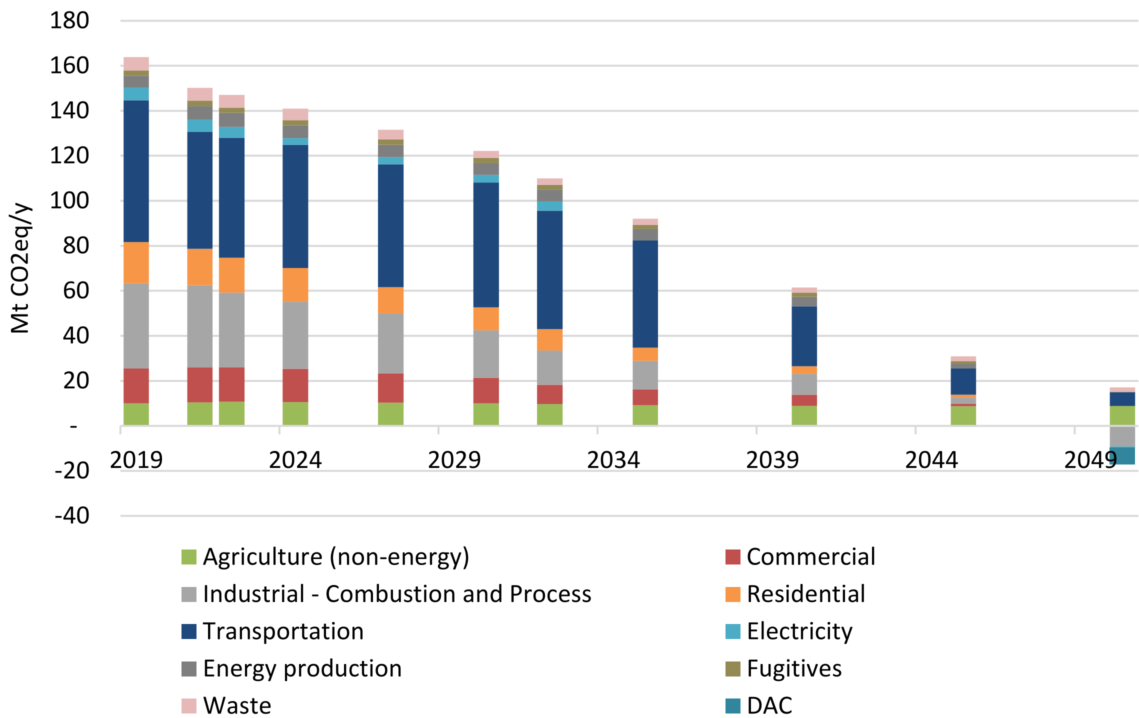


Figure ES-2. Total annual GHG emissions by sector (Mt CO2eq/y) from 2019-2050 for the NZ50 IP (Economy-wide GHG emissions covered by the NIR)

Steering Ontario's economy onto a pathway to achieve net-zero in 2050 will require additional cumulative investments in the order of CAD2022 $173B (in the NZ50 IP) beyond what might occur in the REF IP (Figure ES-3) from 2019 to 2050. **Incremental investment will be primarily concentrated in the electricity sector,** due to the high need for emissions-free electricity supply as well as transmission and distribution infrastructure. Incremental investment in the transportation sector is relatively small, as current policies and technology cost trends already drive significant decarbonization of transportation in REF – however, it should be noted that keeping Ontario on track to achieve the GHG emissions reductions in the REF IP will require significant investment.

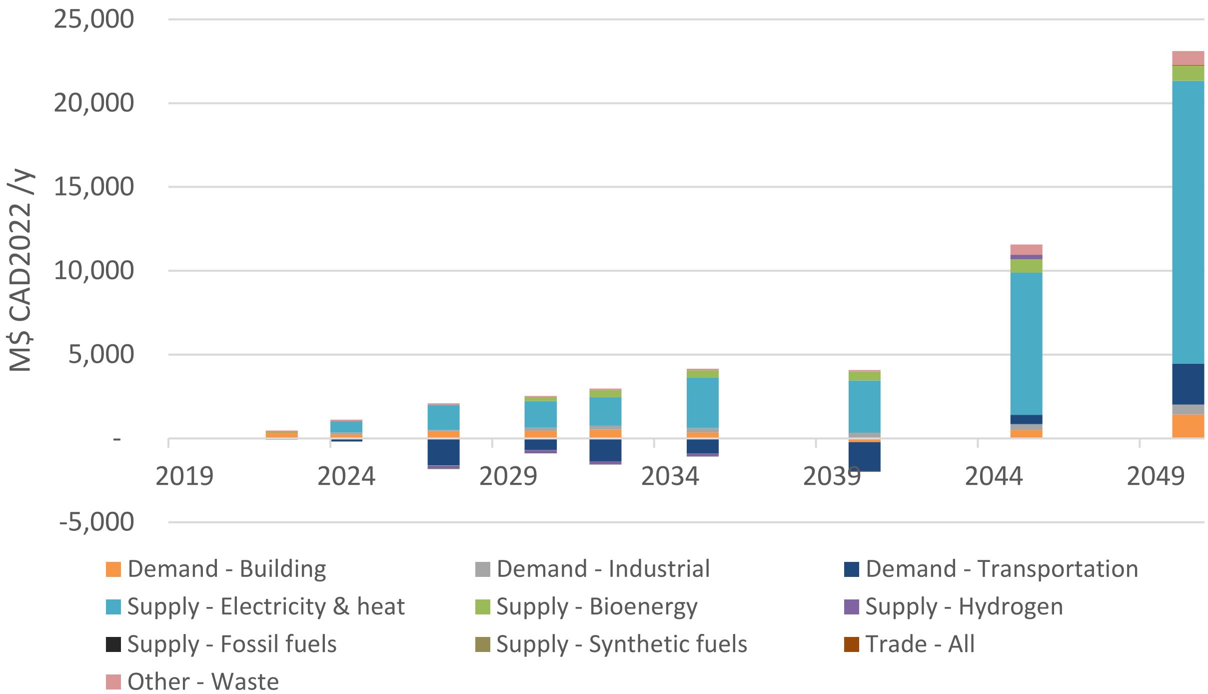


Figure ES-3. Annual incremental investment cost (M$ CAD2022/y) of the NZ50 integrated pathway compared to the REF IP in 2019 to 2050

The transition's positive outcomes on energy affordability and societal co-benefits will offset energy investment costs and GDP impacts

The net-zero transition will have minor impacts on gross domestic product (GDP) and labor demand in comparison to REF, with GDP growth continuing. The incremental impacts of Ontario's energy transition on GDP will be 0.04 percentage points per year[3] lower in NZ50 and off-set by numerous co-benefits. The NZ50 pathway is expected to require more highly skilled workers compared to REF, while demand for lower skilled workers is smaller.

At the same time, average ("normalized") household energy bills are expected to decline substantially, e.g. 47% from 2022 to 2050 in NZ50[4], due to fuel switching and energy savings. However, there is a risk of high energy bills for households remaining on natural gas due to a large drop in consumers in 2045-2050 in NZ IPs.

Additionally, the transition is anticipated to bring significant co-benefits, such as improved health and avoided impacts on agricultural productivity and economic activity, and reduced risk of disruption of energy systems, with cumulative (2019-2050) benefits from avoided damages

[3] Difference in average real annual growth (%/y) (2019-2050) between REF and NZ50.
[4] Without OER and with the legislated carbon price

estimated between CAD2022 $245 billion and $874 billion across NZ IPs (incremental to REF), far outweighing the incremental investments required.

A number of immediate no-regret actions will be critical for the success of Ontario's energy transition

There are nine solutions for 2030 that appear in almost all of the NZ IPs and exhibit little to no variability in the magnitude of uptake (i.e., are no-regret solutions) that should be supported immediately. Early success across these nine solutions will be critical to long-term decarbonization. The nine solutions are:

1. Pursue full economic potential for demand reduction in the building sector through **energy efficiency and building controls**,
2. Pursue the rapid **electrification of residential and commercial space heating** with ASHPs,
3. Pursue the rapid **electrification of light-and medium duty vehicles as well as buses**,
4. Continue to deploy **electricity storage technologies** to meet near-term (before 2030) capacity requirements and peak demand,
5. Deploy **onshore wind** as a solution to meeting near-term 2030 system needs and monitor the need for additional growth by 2050,
6. Build out **electricity transmission and distribution (T&D) infrastructure** within Ontario.
7. Deploy rooftop PV and other distributed energy resources to meet system needs,
8. Continue exploration and **development of SMRs** to reduce first-of-kind deployment risks and work with federal government to ensure that its regulatory processes facilitate timely and safe deployment, to achieve economies of scale and enable significant growth in SMR capacity by 2050,
9. Ramp up the sustainable **utilization of forests** to fulfill the growing demand for biomass.

Other solutions required by 2030 have variability in the magnitude of uptake but appear in almost all of the NZ IPs (i.e., are least-regret solutions) or show less consistency across NZ IPs (i.e. are wild card solutions). However, this does not indicate that no action is required. These solutions will also require action before 2030 if Ontario wishes to pursue modelled least-cost net-zero pathways.

Key **barriers** include lack of awareness, public acceptance, skilled labor shortages, investment uncertainty in new markets i.e. "chicken-and-egg" dynamics, and regulatory challenges. Addressing these barriers will be critical for scaling the necessary fuels and technologies. Further, many solutions for 2050 require significant infrastructure development to support their implementation. Early exploration and developments in some technologies will be key to ensuring that learnings can enable achievement of future cost reductions associated with Ontario-specific barriers.

Advanced planning, decisions, and actions between now and 2030 will have important implications for the success and cost-effectiveness of solutions for 2050.

In the absence of timely decision-making, the cost of implementing solutions for 2050 may become higher, and the risk of not meeting net-zero in 2050 will increase. Inaction or failure to act in a timely manner also risks incurring significant costs on the order of CAD2022 $245 billion and $874 billion by 2050 due to climate change related damages (across NZ IPs, incremental to REF, cumulative from 2019-2050, as quantified by the social cost of GHGs (SC-GHG)), and may have other consequences to health, competitiveness, and affordability.

This study should serve as a starting point for more refined planning by sector. In particular, some areas that warrant further work include assessing the resource adequacy, operability and transmission and distribution requirements for the electricity sector, and regional infrastructure planning. Almost all long-term solutions have initial uptake in the modelled IPs before 2050 and require actions before 2030, including developing regulatory frameworks, encouraging technology adoption and early investment, beginning infrastructure development, developing stable supply chains, and re-training of skilled workers. The design of new policies was out of scope of this study; but constitutes an important next step to direct Ontario's economy towards further emission reductions.

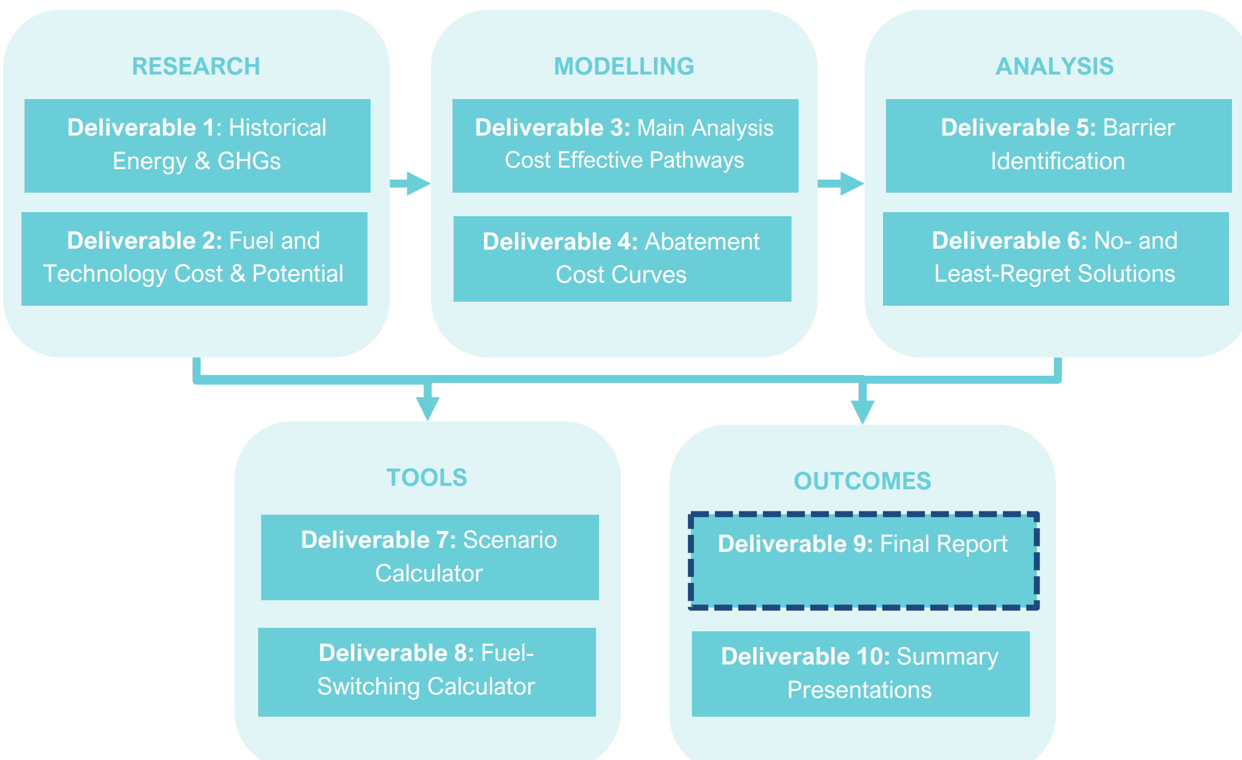
SECTION 1

1. Introduction

1.1 Study Overview

ESMIA Consultants, in collaboration with Dunsky Energy + Climate Advisors, has been commissioned by the Ontario Ministry of Energy and Electrification to conduct an independent Cost-Effective Energy Pathways Study that identifies least-cost pathways to decarbonizing the province's energy system by 2050. The study is intended to provide decision-makers, stakeholders, and communities (including Indigenous communities) in Ontario with insights as to how Ontario's energy sector can best support electrification and the energy transition. In addition to contributing to long-term energy planning in the province, the study has also supported the work of the Electrification and Energy Transition Panel (Panel) and is intended to inform future policy decisions and discussions in Ontario.

As illustrated in the figure below, the study is comprised of 10 key deliverables, each of which is linked through three key project phases, and the tools and outcomes that will be the final outputs of this study.



1.2 Approach

Research

Historical Energy and GHG Emissions

To understand the current state and trajectory of Ontario's energy system and GHG emissions, as well as fine-tune the model and enable comparison of the modelled integrated pathways with historical trends, historical information on energy and GHG emissions in Ontario over the past 10 years was collected for key sectors, fuels, and end-uses. The exercise leveraged publicly available data from federal and provincial governments and their agencies, as well as targeted data requests to key stakeholders (e.g., Independent Electricity System Operator (IESO), Enbridge Gas). This data was then used to analyze key trends in energy and GHG emissions in Ontario over the past 10 years by sector and end-use.

Fuel and Technology Cost and Potential

Key technical and economic parameters (e.g., cost, efficiency, lifetime, achievable supply) for 34 fuels/technologies key to Ontario's energy transition were characterized. This provided data, insights and forecasts of cost, performance (e.g. efficiency) and achievable supply / deployment tuned to the Ontario context to inform the modelling conducted in this study as well as future work by the Ministry.

An initial list of over 60 potential solutions was compiled, focusing on high-value, high-potential options, including high-certainty measures expected to be critical, and high-potential measures with significant uncertainty, and those targeting large emitters.

Based on these criteria and through engagements with the Ministry and the Project Review Committee (PRC), a subset of 34 fuels and technologies were selected, along with a relevant comparator for each. Credible industry and academic resources[5] as well as internal technology databases were leveraged to characterize each fuel and technology.

Where available, Ontario-specific data was leveraged to characterize the fuels and technologies. Where it was not available, the best available data from other representative jurisdictions or regions (for example, Canada) was used. The team conducted targeted engagements with industry stakeholders to gather the Ontario-specific information, data, and insights on the cost, performance, and achievable supply of fuels and technologies, as well as to review key assumptions.

The research provides projections for fuel and technology characteristics out to 2050. Where applicable, three scenarios were characterized that reflect uncertainty in technical performance, costs, or other attributes, comprising a central case that represents the most likely trajectory and low/high cases representing alternative trajectories for technology development. Some of these

[5] Detailed references used are documented in the Deliverable 2 excel workbook appendix.

low/central/high cases for specific technologies were used in the pathways modelling, depending on the IP/SA. Note: some of the results from Deliverable 2 were overridden for the model; where this is the case, the data can be found in the appendices for Deliverable 3.

Modelling

Cost-Effective Pathways

Representing the core component of the study, integrated pathways (IPs) were modeled using an integrated energy system optimization modelling framework to identify the least-cost pathways to meeting energy service demands in Ontario, while respecting resource limitations and energy and climate policy objectives.

Three key models[6] were used to obtain the results and insights presented in this study: (1) the North American TIMES Energy Model (NATEM), the most technologically comprehensive economy-wide energy system optimization model in Canada, covering the entire energy chain from primary production to end-use demand; (2) the North American General Equilibrium Model (NAGEM), a new generation dynamic macroeconomic model; and (3) RateVision, used to evaluate the impact on tariffs[7] for distribution connected gas and electricity consumers. Detailed energy system results from NATEM are soft-linked to the other two models, ensuring coherence in the modelling approach. Detailed model descriptions are available in Appendix A.

Appendices B & C of Deliverable 3: Cost-Effective Pathways provide detailed documentation of the assumptions used in the study, including a list of modeled technologies / fuels and corresponding key assumptions (e.g., costs), demand projections, a list and description of modeled policies, and other key variables.

The models were used to produce projections of different cost-effective energy pathways for Ontario:

- **A reference case** integrated pathway (REF IP) that reflects Ontario's trajectory under business-as-usual, including committed policies;
- **10 Net-Zero Integrated Pathways (NZ IPs)**, of which 9 reflect plausible future pathways for Ontario's energy system under different market and policy conditions, and each with a GHG constraint of net-zero GHG emissions in 2050;
    - **One NZ IP, the H2+ IP,** is a favourable hydrogen pathway which exceeds the level of plausibility used in the other integrated pathways. A production tax credit for electrolytic hydrogen was added to get to material levels of hydrogen uptake above and beyond what is seen in the other NZ IPs. Due to this, the IP is often an outlier compared to other pathways, and should be interpreted with care;

[6] NATEM, NAGEM, and RateVision are developed and operated by ESMIA (www.esmia.ca)

[7] The term "tariffs" refers to both fixed charges and variable rates.

- **8 Sensitivity Analyses (SA)** that capture the impact of key uncertainties around the pace of cost declines and availability / supply for new technologies on targeted IPs.

The choice of pathways and sensitivities was determined based on guidance from the Ministry, with input from the Project Review Committee. Table 1-1 below provides brief descriptions of the IPs modeled in the study. Detailed assumptions for the IPs, as well as a list of SAs modeled, are presented in Appendix B.

The results presented in the report are largely focused on the reference (REF) and the NZ50 IP. Insights from other IPs and SAs are presented where notable trends that deviate from REF or NZ50 are observed.

Table 1-1. Description of Integrated Pathways Modeled in the study.

IP Number	Label	Description
IP0	**REF**	"Business-as-usual" including committed policies.
IP1	**NZ50**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies.
IP2	**ELC +**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to committed policies. Favourable electrification conditions.
IP3	**ELC HP**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to committed policies. Unfavourable electricity cost conditions.
IP4	**2030-30%**	GHG reduction of 30% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies.
IP5	**H2 +**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to committed policies. Favourable hydrogen conditions and production tax credit for electrolytic hydrogen.
IP6	**2030-50%**	GHG reduction of 50% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies.
IP7	**BIO +**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Favourable biomass conditions.
IP8	**ELC -**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Unfavourable electrification conditions.

IP Number	Label	Description
IP9	**CCS -**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Unfavourable CCS and NET conditions.
IP10	**TRADE +**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Favourable energy trade conditions.

Abatement Cost Curves

Building on the pathways modelling results, abatement cost curves (ACCs) were generated to analyze the cost-effectiveness of various GHG reduction measures across different sectors of the economy. The curves highlight the cost per tonne of carbon dioxide equivalent ("abatement cost", CAD2022/t CO2eq) resulting from different levels of GHG emissions reductions. Each point on the curve represents different abatement measure(s), with their corresponding cost. In contrast to typical marginal abatement cost (MAC) curves, in this study, the ACCs were developed using a system approach, by using NATEM e.g., the full energy value chain and cross-sectoral interactions across the economy are accounted for. Short-term (2030) and long-term (2050) ACCs were developed, focusing on the incremental costs needed to achieve GHG reductions of 40% by 2030, and net-zero by 2050.

Analysis

Barrier Identification

Based on the pathways modelled, barriers to scaling key fuels and technologies in Ontario were identified. Fuels and technologies were selected based on their: significant increase in use in the IPs and SAs, high uncertainty across IPs and SAs, or unique deployment conditions. Technologies with less than 1% contribution to Ontario's supply or demand were excluded. Engaging with the Ministry and PRC, 28 fuels and technologies were selected for barrier identification.

Recognizing the IPs represent a least-cost future state based predominantly on economic optimization, it is important to acknowledge that various barriers may impact their feasibility and realization. Key barriers affecting the fuels and technologies were identified along the following six critical dimensions: market, technical, financial, regulatory, social/cultural, and environmental.

While many of the barriers may be cross-jurisdictional and pertain to technology risks, global economic conditions, or other considerations, the analysis focused on key barriers along these six dimensions and Ontario-specific challenges to scaling the use of the selected key fuels and technologies.

No-and Least-Regret Solutions

Based on modelling results, solutions for achieving net-zero in Ontario were divided into three categories: no-regret, least-regret, and wild cards. This categorization was based on three criteria: significance (degree of uptake relative to other technologies), consistency (appearance across all IPs, excluding REF and H2+), and variability (magnitude of contribution variance across IPs with significant uptake).

A long list of potential solutions was developed based off fuels and technologies that appear across the modelled IPs. The threshold for "significant uptake" (e.g., capacity of electricity generation, percentage of vehicle stock, percentage of useful heat supplied, MtCO2eq/y sequestered) was determined on a case-by-case basis for each fuel and technology.

Solutions that were deemed to have significant uptake in at least one NZ IP were then assessed for their consistency and variability across the NZ IPs and subsequently classified as either no-regret, least-regret, or wild card solutions.

This Report

This report, as one of the final outcomes of the Cost-Effective Pathways Study, consolidates and summarises the key insights from Deliverables 1-6. It presents critical findings from the research, modelling and analysis phases regarding where Ontario is today, cost-effective pathways for Ontario's future energy system, potential impacts of and barriers to these pathways, and key solutions for Ontario's energy future.

In assessing cost-effective pathways to net-zero, this study **provides insight into the essential fuels, technologies and solutions for Ontario to seize the enormous opportunity of the energy transition and secure a prosperous, competitive, net-zero future.**

SECTION 2

2. Why Net-Zero?

2.1 Global View

A global energy transition is underway, driven by declining clean technology costs, increasing consumer and investor demand, and ambitious policy commitments from over 140 countries pledging to achieve net-zero GHG emissions.[8]

Net-zero commitments now cover 88% of global emissions and 90% of global GDP.[9] These commitments align with the scientific consensus that reaching net-zero emissions by 2050 is necessary to limit global warming to 1.5°C and mitigate the worst impacts of climate change.[10]

Global investment in clean energy has surged in recent years, with global investment in clean energy now almost double that of fossil fuels.[11] In 2024, global energy investment is projected to reach a record US$3 trillion per year (nominal), with nearly two-thirds directed towards clean energy technologies and infrastructure.[12]

Major economies are exploring Carbon Border Adjustment (CBA) mechanisms to maintain economic competitiveness while reducing emissions, and the European Union (EU) has a CBA that transitions into effect in 2026.[13] This global alignment towards decarbonization presents both a challenge and an opportunity for economies worldwide to transition to cleaner energy systems and foster economic growth through innovation and decarbonization.

2.2 Ontario's Opportunity

Ontario is positioned for success in the global energy transition

The province's electricity grid is largely emissions-free, thanks to historic investments in hydropower and nuclear energy, and previous initiatives to phase out coal-fired generation. As of 2023, 87.5% of Ontario's electricity output is emissions-free, positioning it favorably compared to many advanced economies and major trading partners.[14] Ontario's low emissions intensity and reliable, cost-competitive energy supply provide a strong foundation for future growth.

In 2023 the province launched a Clean Energy Credit (CEC) registry, designed to facilitate the tracking and trading of clean energy credits, which can be purchased and retired by businesses to meet their environmental and sustainability goals, positioning Ontario to respond to increasing commitments from companies to procure clean energy.

[8] International Energy Agency. World Energy Outlook 2023
[9] United Nations. Climate Action; International Energy Agency. World Energy Outlook 2023
[10] United Nations. Climate Action;
[11] IEA. World Energy Investment 2024.
[12] *Ibid.*
[13] European Commissions. Carbon Border Adjustment Mechanism;
[14] Ontario Energy Board (OEB). 2024. Ontario's System-Wide Electricity Supply Mix: 2023 Data

For Ontario, transitioning to a net-zero economy offers multiple benefits beyond mitigating climate change. By pursuing net-zero, Ontario can attract investment, create new green jobs (not modelled), and drive innovation in clean technologies (not modelled). This transition also provides an opportunity to improve public health (not modelled), reduce energy costs, and reduce energy-related trade deficits.

2.3 Risks of Inaction

There are economic, environmental, and social consequences that would result from failing to move beyond a business-as-usual pathway, which includes committed policies and actions. Inaction or failure to act in a timely manner risks incurring significant cumulative costs (2019-2050) on the order of CAD2022 $245 billion and $874 billion due to climate change related damages (as quantified by the SC-GHG, across NZ IPs, incremental to REF, see section 6.3) in addition to other consequences related to health, competitiveness, and affordability.

Economic

Without proactive measures, Ontario faces significant risks to affordability. Delaying investments in key technologies and infrastructure will lead to higher costs in the long run. Early planning and investment are crucial for cost-effective pathways to net-zero; hesitation will only increase costs and complicate the transition. For instance, the uptake of Heavy-Duty Zero Emission Vehicles (HD ZEVs) is contingent on supporting infrastructure. Development timelines for these technologies span 5+ years, and delays will slow down market penetration, increasing the eventual costs of adoption and reducing Ontario's competitiveness (not modelled) in the global market.

Inaction will also impact household energy affordability. Zero emissions energy sources could be less expensive than fossil fuels and adopting clean technologies, such as electric vehicles (EVs) and heat pumps, can generate significant cost savings for Ontarians. If done right, the energy transition will save households money by reducing reliance on fossil fuels and taking advantage of more efficient, cleaner technologies.

Failing to act could hinder Ontario's ability to manufacture and trade goods globally (not modelled). As major economies like the EU implement CBAs, Ontario's products could become less competitive if they are not produced with low-carbon methods. This shift towards greener products, driven by both regulatory requirements and changing consumer preferences, could lead to job losses and diminished economic growth if Ontario fails to adapt.

Building out clean energy infrastructure efficiently is critical for attracting investment in sectors essential to Ontario's low-carbon economy (not modelled). Businesses and industries globally are increasingly prioritizing reliable and affordable clean electricity to power their operations. If Ontario fails to build out and decarbonize its electricity grids, crucial investment in sectors such as green steel production and EV manufacturing may flow elsewhere. Ontario has made early progress towards this with Powering Ontario's Growth Plan as a first step, and further efforts are needed.

Health and Environmental

Without achieving net zero or negative GHG emissions for its own economy and imports, Ontario will continue to contribute to global climate change, facing more frequent and severe weather events. These changes will have direct impacts on agriculture, infrastructure, and overall quality of life. Increased occurrences of extreme weather, such as floods and heatwaves, will strain public resources and lead to higher costs for disaster response and recovery. Both changing weather patterns and extreme weather events can jeopardize Ontario's ability to produce, transport, and distribute energy, with significant societal costs. Investments to increase infrastructure resilience to weather events will increase costs, e.g. for ratepayers or taxpayers. Without action to reduce GHGs, these costs will continually increase.

Health impacts are also a concern. Continued reliance on fossil fuels and increases in forest fires will result in higher levels of air pollution, which is linked to respiratory and cardiovascular diseases. Increasing frequency and severity of heatwaves will also result in an increased risk of heat stroke and heat-related deaths.

Indigenous communities, and particularly those in northern and remote regions of Ontario experience disproportionate impacts of climate change. Extreme weather events can exacerbate existing inequities including respiratory, cardiovascular, water, foodborne, chronic and infectious diseases, as well as financial strain and food insecurity.

The transition to a net-zero economy offers a chance to improve public health by reducing pollutants that contribute to chronic illnesses. Failing to make this transition will maintain, if not exacerbate, current public health challenges.

Cascading Effects of Global Inaction

If other regions do not take sufficient action to address climate change, impacts including trade disruptions, transboundary pollution, impacts to food security, climate refugees, increased climate risks and increased risks of conflict may cascade onto Ontario.

Ontario's economy is highly integrated with global markets. If other jurisdictions fail to act on climate change, supply chains may be disrupted due to climate-related events such as extreme weather, impacting the availability and cost of goods. This could lead to increased production costs for Ontario's industries, reducing their global competitiveness.

Air and water pollution do not respect borders. If neighboring jurisdictions do not reduce GHG emissions, Ontario could suffer from transboundary pollution, leading to degraded air and water quality. This would exacerbate health issues such as respiratory and cardiovascular diseases among Ontario's population.

Climate change also poses significant risks to food security. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events disrupts food production processes and can lead to decreased crop yields and increased prevalence of pests and diseases. Ocean warming, acidification and deoxygenation also threatens to degrade marine ecosystems, impacting fisheries and aquaculture. Extreme weather events can also affect the stability of food supply, for example through impacts to infrastructure and disruption of transportation.

Failure to act on climate change globally could result in increased migration from areas severely affected by climate impacts. Ontario may face an influx of climate refugees, which could strain social services and infrastructure, requiring substantial public investment to accommodate and integrate these populations.

Global failure to mitigate climate change will likely result in more severe and frequent weather events. Ontario could experience heightened risks of floods, droughts, and heatwaves, which would impact agriculture, infrastructure, and overall public health and safety. These events would lead to increased costs for disaster response, recovery, and adaptation measures.

SECTION 3

3. The History

3.1 Historical Energy & GHG Trends in Ontario

Over the last decade, Ontario has experienced economic growth with relatively stable energy consumption and GHG emissions.

In 2019, Ontario emitted 166 million tonnes per year of GHGs, measured in carbon dioxide equivalent units (Mt CO2eq/y)[15] and consumed 3,047 PJ/y of energy. Energy demand grew by less than 1% per year on average between 2010-2019, and GHG emissions decreased by 0.5% per year on average (Figure 3-1).[16] GHG emissions had a consistent decline from 2010 to 2017 (by 1.2% per year on average), followed by a 5% increase from 2017 to 2018, then declined through 2019. Between 2019 and 2020, many of these historic trends were disrupted due to the COVID-19 pandemic, discussed further below.

While Ontario's energy demand and GHG emissions remained relatively stable from 2010-2019, the province's emissions intensity decreased as activity metrics increased (population, employment, travel, floor space, and GDP). Per capita GHG emissions have trended down, (declining from 13 t CO2eq per person per year in 2010 to 10 t CO2eq per person per year in 2019, a 23% decline) (Figure 3-2).[17] Similarly, annual energy use per capita declined by 6%. These trends show that **Ontario could be moving towards an era where GHG emissions are decoupled from economic and population growth.**

This section summarizes key highlights and findings from Deliverable 1: Historical Energy and GHG Emissions. For further details, readers can refer to Deliverable 1.

[15] GHG emissions in this section, and in the majority of the report reflect the reporting scope of Canada's official GHG inventory, also known as the National Inventory report ("NIR", Government of Canada, 2022) but excluding impacts of Land-Use, Land-Use Change and Forestry (LULUCF). The study scope for energy and emissions is slightly larger than the NIR as explained below but the difference is small and using NIR data avoids potential data misalignment.

[16] Government of Canada, "Environment and Climate Change Canada data : Canada's official greenhouse gas inventory," 2022. [Online]. Available: https://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/?lang=en.
Statistics Canada, "Table: 17-10-0005-01 Population estimates on July 1st, by age and sex," [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501&pickMembers%5B0%5D=1.7&pickMembers%5B1%5D=2.1&cubeTimeFrame.startYear=2010&cubeTimeFrame.endYear=2022&referencePeriods=20100101%2C20220101. [Accessed 2023].
Statistics Canada, "Table: 36-10-0222-01 Gross domestic product, expenditure-based, provincial and territorial, annual (x 1,000,000)," [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610022201 . [Accessed 2023].
NRCan - Natural Resources Canada, "Comprehensive Energy Use Database," 2019. [Online]. Available: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm.

[17] All values are annual for year shown, GDP is in 2022 CAD.

Activity is increasing at a faster pace than energy consumption and GHG emissions.

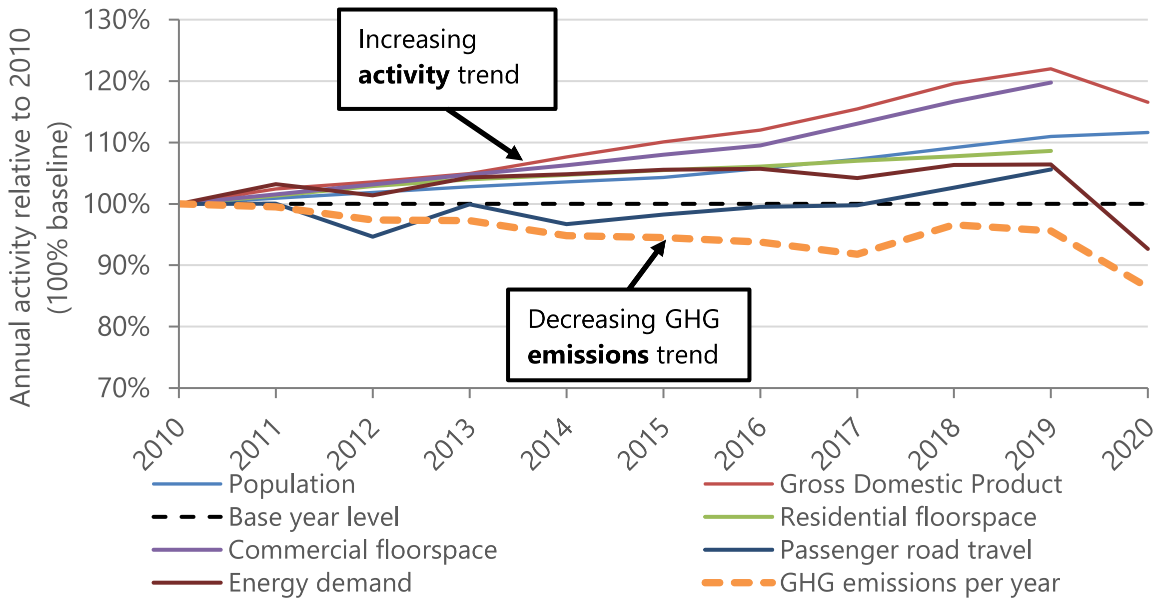


Figure 3-1. Annual activity for years 2010 to 2020, relative to 2010, which is the baseline of 100%

Energy demand and GHG emissions intensity is declining.[18]

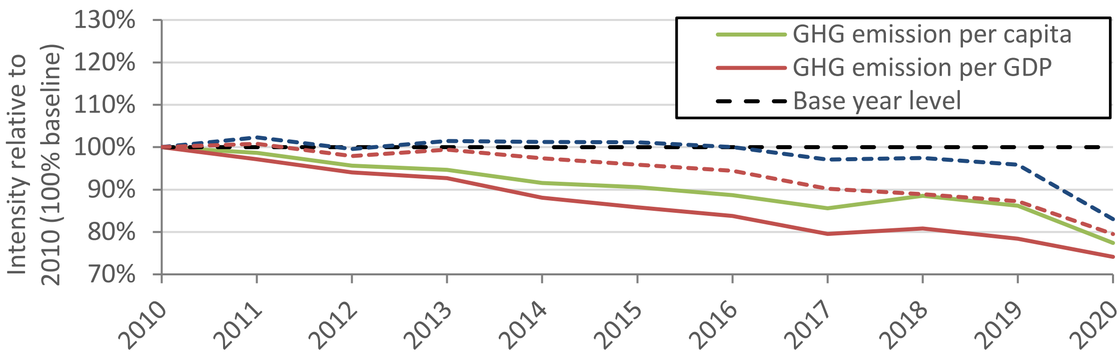


Figure 3-2. Index changes (per capita and GDP) relative to 2010, which is the baseline of 100%

[18] Government of Canada, "Environment and Climate Change Canada data : Canada's official greenhouse gas inventory," 2022. [Online]. Available: https://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/?lang=en.
Statistics Canada, "Table: 36-10-0222-01 Gross domestic product, expenditure-based, provincial and territorial, annual (x 1,000,000)," [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610022201 . [Accessed 2023].

At a high level, Ontario's GHG and energy demand trends have remained relatively consistent over the past decade.

Historically, from 2010 to 2020, most of Ontario's GHG emissions are due to energy use, including fossil fuel combustion for transportation (35% to 38% of total emissions) and heat (stationary combustion, 36% to 42% of total) (Figure 3-3). Over this same timeframe, industrial processes and products use[19] account for between 12% to 16% of total emissions, agriculture accounts for 5% to 7%, waste accounts for 4% to 5%, and fugitives (emissions released during oil and gas exploration, production, transportation, and distribution) represent approximately 1%.

Since 2010, total GHG emissions have decreased by 23 Mt CO2eq/y. [20]

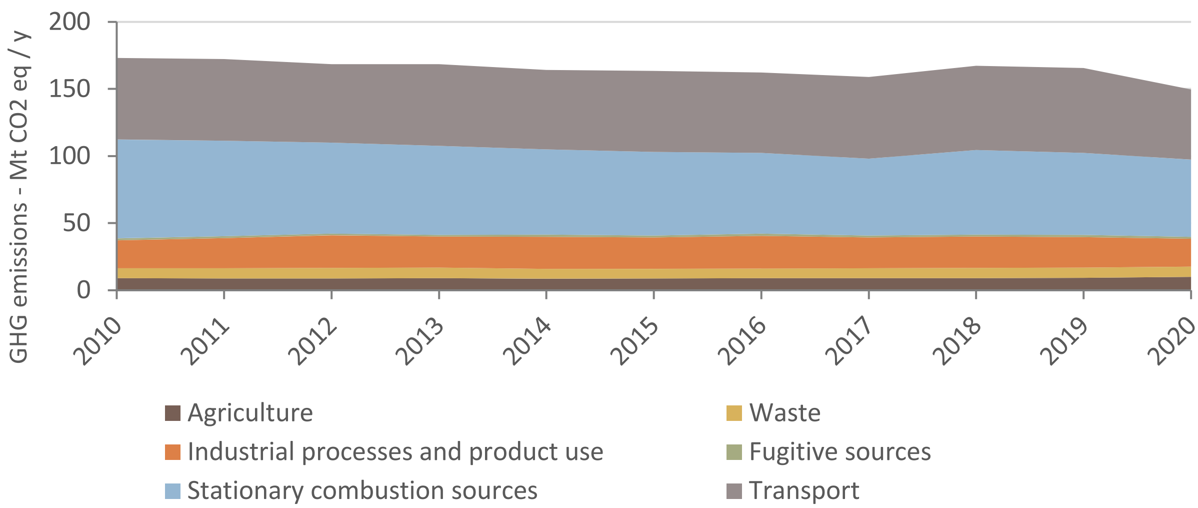


Figure 3-3. Ontario GHG emissions by source (IPCC category), NIR scope (Mt CO2eq/y) from 2010 to 2020

Refined petroleum products (RPP) and natural gas have historically made up the majority of Ontario's secondary energy demand (40% and 33%, respectively), followed by electricity (18%) in 2021. The "other" category – which includes coke and coke oven gas, natural gas liquids, steam, wood waste and pulping liquor – makes up 9% in 2021 (Figure 3-4).

[19] This category includes non-combustion emissions resulting from the production of cement, lime, minerals, metals, and chemicals. It also includes consumption and use of halocarbons, solvents, non-energy use of fossil fuels, and other product use and manufacture.

[20] Government of Canada, "Environment and Climate Change Canada data : Canada's official greenhouse gas inventory," 2022. [Online]. Available: https://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/?lang=en.

RPP and natural gas made up 73% of Ontario's secondary energy demand in 2021. [21]

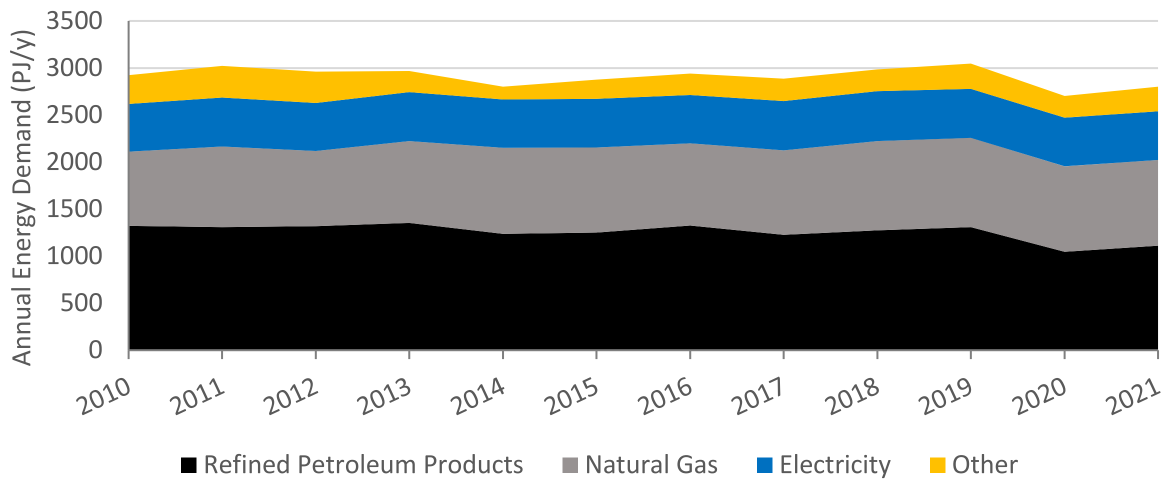


Figure 3-4. Ontario secondary energy demand (PJ/y) by energy type in 2010-2021

Other key trends and inflection points

There are several key trends and inflection points illustrated by the energy and GHG emissions data collected for this study.

Phase-out of coal-fired electricity generation: In 2001, the Government of Ontario committed to stop burning coal at the Lakeview Generating Station, and appointed the Select Committee on Alternative Fuel Sources, which advised to phase out coal-fired electricity generation. In 2003, the government committed to closing the province's four remaining coal-fired power plants. Ontario succeeded in phasing out coal-fired electricity generation, from >12 TWh/y in 2010 to zero in 2014. Due to this phase-out, GHG emissions from electricity generation decreased from 20 Mt CO2eq/y in 2010 to 6 Mt CO2eq/y in 2014, while in-province electricity generation increased from 152 TWh/y to 158 TWh/y, leading to a steady decline in the carbon intensity of Ontario's electricity.

Increased Capacity of Solar and Wind: Since 2010, Ontario's fleet of solar and wind electricity generators increased from less than 2 GW of installed capacity in 2010 to 8.7 GW in 2021. Consequently, the percentage of Ontario's electricity generated from solar and wind has also

[21] Statistics Canada, "Table 25-10-0029-01 Supply and demand of primary and secondary energy in terajoules, annual," 2022. [Online]. Available: https://doi.org/10.25318/2510002901-eng. [Accessed 2023]. "Secondary energy" refers to energy after all energy to energy conversions, e.g. electricity made using natural gas is secondary energy, but not the natural gas used to produce that electricity. Secondary energy includes demand for fuels for non-energy uses, such as lubricants and petrochemical feedstocks. "Secondary energy demand" is used interchangeably with "final energy demand".

increased from <2% to approximately 9%. The Feed-in Tariff (FIT) program was a significant driver of this, with most of these increases occurring between 2010 and 2016.[22]

Rate relief policies and programs: Electricity rates and residential bills in Ontario have varied significantly in response to rate relief policies and programs implemented by the government, in particular the Fair Hydro Act of 2017, which reduced prices by approximately 25% and limited price increases in 2018 and 2019. The Ontario Electricity Rebate and other special COVID-19 pandemic measures, as mentioned previously, also impacted rates post-2019.

EV Incentives: Although EVs still make up a small share of Ontario's overall transportation market, the sales of light-duty BEVs and plug-in hybrid electric vehicles (PHEVs) have been increasing since 2010. Increases in sales have been highly correlated with access to incentives and rebate programs – for example, the introduction of a provincial EV rebate program in 2010 contributed to increasing sales, and there was a notable decrease of 42% in sales between 2018 and 2019 when the provincial EV rebate program was terminated. The introduction of a federal rebate program (along with the influence of other pressures such as post-COVID-19 pandemic recovery and increasing gasoline prices) caused sales to increase again in 2021.

Annual GHG intensity in the residential, industrial, and personal transportation sectors declined during the past decade[23]. While it is difficult to link these overall declines to a single particular policy, several policies implemented by the government and other actors over the past decade have likely contributed, including the renewable content requirements for gasoline and diesel[24], the Ontario Building Code, various demand side management programs, the Green bond program, nuclear refurbishment programs, Provincial energy efficiency standards for products, appliances, and equipment, and regulatory changes and investments for reducing the use of coal in energy-intensive industries.[25]

Energy intensity of the residential buildings, passenger transportation, and freight transportation sectors has also declined during the past decade – while both energy and activity have been generally increasing (with the exception of COVID-19 pandemic impacts), the growth in activity (such as building floor space, passenger-kilometers per year, and tonne-kilometers per year) has outpaced growth in energy consumption.

[22] While the FIT program significantly increased renewables capacity, it also faced criticism for contributing to increased electricity costs due to the high rates guaranteed to renewable energy producers which were passed on to consumers through the Global Adjustment Fee.

[23] Percent decline is calculated as intensity in 2020 relative to intensity in 2010.

[24] Current regulation is the Cleaner Transportation Fuels regulation (O. Reg. 663/20), but versions of the renewable content requirements for transportation fuels have been implemented in Ontario since 2005.

[25] This analysis focused on historical trends between 2010-2021 (or 2020, depending on data availability). However, it is worth noting that in 2022 the Government of Ontario, in a joint effort with the federal government, further committed to reducing the use of coal in energy-intensive industries, providing funding for the phase-out of coal fired furnaces at two steel plants, Algoma Steel and ArcelorMittal Dofasco. These plans were included in the pathways modelling.

Ontario is among the leading jurisdictions in a jurisdictional comparison of energy and emissions benchmarks for reducing GHG emissions

Compared to other jurisdictions, Ontario has made strong progress towards decarbonization in the last 10 years, with the coal phase-out policy being key to reducing the GHG intensity of electricity generation.

Overall, the province has a lower electricity GHG intensity and higher electricity use than many Canadian provinces, California and New York, but lags behind Norway, Quebec, and British Columbia on current GHG intensity (Figure 3-5, Figure 3-6).

Ontario's GHG intensity of the economy decreased by 26% in 10 years. [26]

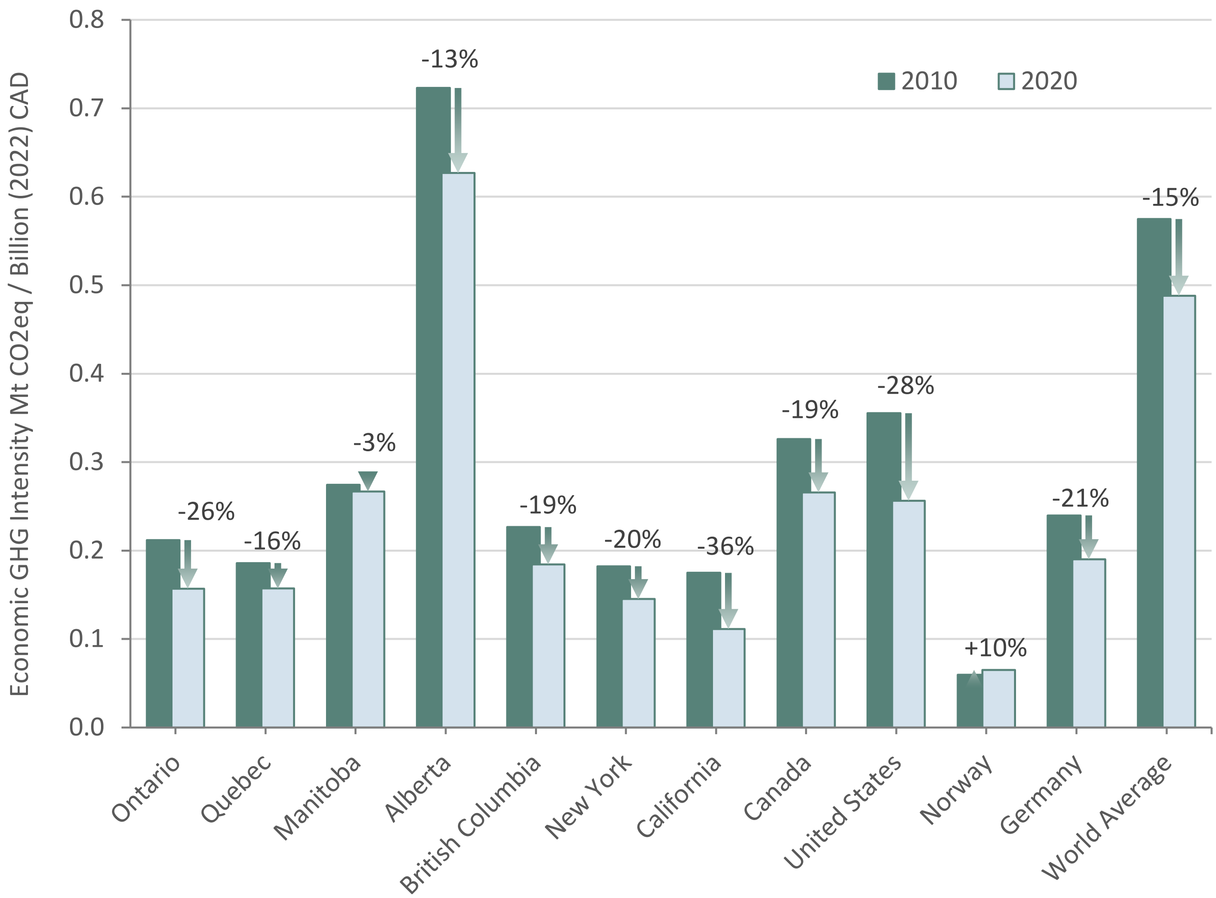


Figure 3-5. GHG intensity of the economy by jurisdiction (Mt CO2eq/y / Billion CAD2022 GDP/y) for 2010 and 2020

[26] Several sources were used to compile this figure. Refer to Deliverable 1 for details.

Ontario's electricity grid GHG intensity dropped by 81% in 10 years.[27]

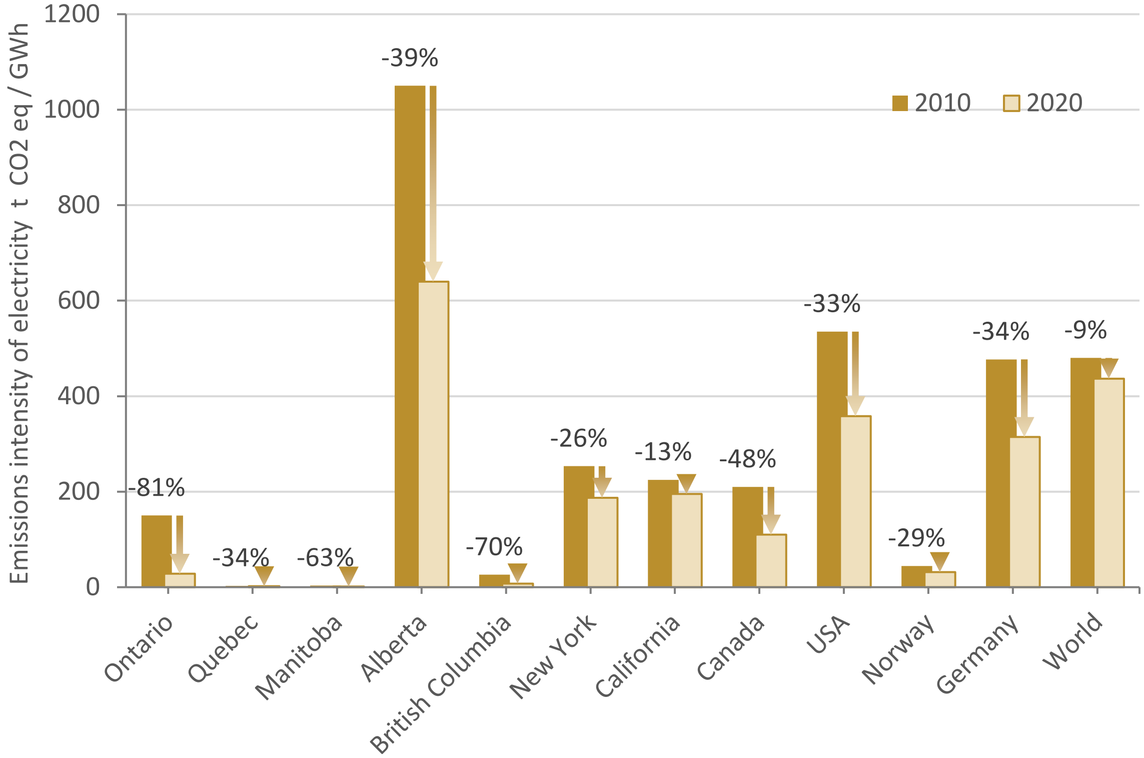


Figure 3-6. Electricity grid intensity by jurisdictions (t CO2eq/y / GWh/y) for 2010 and 2020

To reach net-zero, Ontario must build on past successes

Achieving net-zero by 2050 will require further significant GHG emissions reductions across all sectors. Ontario has made great progress to date in decoupling GHG emissions from economic growth and decarbonizing its electricity system. These efforts have positioned Ontario for success in the global energy transition. To reach net-zero and capitalize on the economic opportunities of the energy transition, the province will need to build on its progress to date by advancing rapid decarbonization across all sectors of the economy.

[27] Several sources were used to compile this figure. Refer to Deliverable 1 for details.

SECTION 4

4. The Tools

4.1 Key Fuels & Technologies for Ontario's Energy Future

Several fuels and technologies will be critical for a cost-effective energy transition

Achieving net-zero GHG emissions by 2050 in Ontario will involve the integration of new fuels and technologies, each with their own set of costs, uncertainties, and infrastructure requirements. There is inherent uncertainty regarding future technology mix, however, certain fuels and technologies can be expected to play a key role in Ontario's cost-effective energy transition. This section provides a description of these key fuels and technologies, as well as an overview of uncertainties and considerations for their integration into Ontario's energy system.

> This section summarizes key highlights and findings from Deliverable 2: Fuel and Technology Cost & Potential. For further details, readers can refer to Deliverable 2.

Growing and decarbonizing Ontario's electricity generation

In the electricity sector, electricity demand is expected to grow significantly to 2050, with electricity generation capacity anticipated to more than double by 2050.[28] Several technologies are expected to play a role in meeting this future demand:

- **Small Modular Reactors (SMRs):** Over 50% of Ontario electricity generation is currently from conventional nuclear power. With 18 reactors in 3 locations, Ontario owns a net-capacity of 13 GW which corresponded to 79 TWh generated in 2023.[29] Nuclear power generation is in general well accepted and there are no major constraints for nuclear generation expansion.

In the transition to net-zero, SMRs are projected to play a role in providing low-emission, reliable electricity. These advanced nuclear reactors are designed to be smaller and more flexible than traditional nuclear power plants, offering scalable deployment potential. SMRs come in multiple designs, with no single dominant design, and investment costs are extremely high and highly variable. Types of SMRs include light-water small modular reactor, gas-cooled small modular reactor, molten salt small modular reactor, and liquid metal cooled reactor. There are over 50 SMR designs, most of which are still in the early stages of prototyping[30], and among them a wide range of power levels, designs, and end-user applications, making site-specific design more complex

[28] Independent Electricity System Operator. Pathways to Decarbonization.
[29] Independent Electricity System Operator. Supply Overview.
[30] IESO. 2022. Pathways to Decarbonization.

and time-consuming. Cost declines are uncertain and will depend on technological advancements in the coming years.

Given these and other uncertainties, the role of SMRs in Ontario's clean energy transition is subject to uncertainty relative to more proven, mature technologies.

Despite these uncertainties, Ontario is a global leader in SMRs. While there are no SMRs currently operating in Ontario, the province is currently building four first-of-a-kind grid-scale SMRs at the Darlington nuclear site. The first of these is expected to enter commercial operation in 2029 (assumed to be 2028 in the model).

- **Onshore wind** turbines have blades that convert the kinetic energy in wind to electricity. Onshore wind is a mature and low-cost technology with significant potential for reducing GHG emissions.

However, several factors may constrain wind development in Ontario. For example, there are acoustic constraints related to regulations on maximum allowable noise levels for wind energy projects in Ontario. Siting and permitting, transportation limitations, and community concerns are considered the primary constraints for onshore turbines. Additionally, interconnection policies, processes, and costs often delay or limit the potential and pace for deploying onshore wind resources. The limited availability of skilled labour, installation and assembly equipment (hoists, cranes) can pose a constraint.

- **Long-duration energy storage (LDES)** refers to technologies that can be used to store electricity and dispatch stored energy for an extended period, typically longer than 8 hours. Numerous technologies exist today or are under development. These technologies are critical for supporting grid stability and integrating intermittent renewable energy sources. They offer low-cost solutions with limited technical and financial barriers. Longer-duration storage (e.g., pumped hydro, 8-hour vs. 4-hour batteries) will be important for ensuring resource adequacy needs. As of 2024, Ontario has recently completed the largest battery storage procurement in Canada's history, including a mix of both short- and long-duration battery storage projects.

Electrifying and improving efficiency of Ontario's buildings

In the buildings sector, aligning with net-zero GHG emissions will require electrifying building systems, while also taking further action to improve building efficiency. Several technologies are expected to play a key role in this sector:

- **Air Source Heat Pumps (ASHPs)** are electrically driven devices that provide heating and cooling by extracting heat from a low temperature place (a source) and delivering it to a higher temperature place (a sink). In heating mode, the heat pump draws heat from the outside air and delivers it inside the home. In cooling mode, it operates in reverse, drawing heat from air inside the home and rejecting it outside.

ASHPs are expected to play a central role in decarbonizing space heating (while also replacing air conditioners and providing space cooling). Their efficiency and potential to significantly reduce GHG emissions make them a critical technology for Ontario's building sector. ASHPs are approaching cost parity on a total cost of ownership basis with traditional heating systems, which is anticipated to drive their widespread adoption. Barriers to the adoption of ASHPs include workforce constraints, technical and financial barriers, and supply chain constraints.

- **Retrofit and Controls:** Retrofitting existing buildings with energy-efficient technologies and advanced controls are expected to be vital measures for improving the energy performance of Ontario's aging building stock. Despite the high upfront costs associated with retrofits, there are long-term savings and GHG emissions reduction potential. Financial incentives and increased public awareness are key to accelerating the adoption of these measures.

- **District Energy Systems (DESs)** provide heating and cooling to multiple buildings through a network of distribution pipes connected to centralized heating and cooling centres. DESs are currently available, and Ontario has systems currently operating in Toronto, Hamilton, Ottawa, London, Markham, Sudbury, Cornwall, and Windsor.

  A DES requires a high density of heating or cooling demand to be cost-effective. In areas where buildings are densely populated, less piping and trenching is required, and there are fewer losses associated with heat distribution. However, installing a DES in an existing densely populated area can be challenging and costly. Potential barriers include land constraints, disruption, congested right-of-way, lack of regulatory framework, and lack of funding and policy support. Challenges associated with DES are also highly dependent on the fuels and technologies used – for example, a DES leveraging waste heat from SMRs may face public concern associated with the perceived risks of nuclear power.

Powering Ontario’s vehicles with clean energy

In transportation, electrifying and decarbonizing light-duty transportation is already well underway, while a range of options for decarbonizing medium-and-heavy-duty transportation are emerging. Key fuels and technologies expected to play a role in decarbonizing the transportation sector include:

- **Light-Duty Battery Electric Vehicles (LD BEVs):** BEVs use electricity stored in a battery pack to run an electric motor for propulsion. BEVs have no tailpipe emissions. All energy is stored in battery packs which are recharged from the grid using electrical vehicle supply equipment (EVSE), more commonly referred to as EV chargers.

  LD BEVs are nearing cost parity on a total cost of ownership basis with internal combustion engine vehicles (ICEVs) and are widely expected to be a key technology for reducing transportation GHG emissions.

Ontario-specific constraints include a lack of provincial rebates or incentives on new BEVs or associated home charging equipment. Furthermore, there may be limited supply available due to a lack of Ontario ZEV sales mandate.

- **Heavy-Duty (HD) BEVs:** BEVs are also expected to play a role in decarbonizing medium- and heavy-duty transportation. However, uptake is constrained by several factors. There are two methods of charging for long-haul trucks: depot charging and public charging networks. Currently, there is insufficient high-power charging capacity to support HD-BEVs along the traditional trucking highway corridors in Ontario (or Canada). Fleet owners looking to transition to BEVs will also need to factor in the costs of purchasing and installing charging stations within their depots to support their electric trucks. The potential installation of high-power chargers along highway corridors across the province will require necessary transmission and distribution (T&D) capacity as well as coordination with local utilities.
- **Fuel Cell Electric Vehicles (FCEVs):** HD-FCEVs are powered by hydrogen. HD-FCEVs use a propulsion system powered by electricity produced by conversion from hydrogen in a fuel cell, whereas typical heavy-duty internal combustion vehicles (HD-ICEVs) use diesel. The only tailpipe emissions from HD-FCEVs are water vapor and warm air. Hydrogen gas is stored in a tank on the vehicle that can be refueled within a similar refuelling time to a traditional ICE vehicle.

  The biggest barrier to FCEV adoption is that these vehicles depend on hydrogen refuelling stations, which Ontario currently lacks.

- **Catenary Systems (CAT)** supply electricity to heavy-duty trucks through overhead wires and a pantograph, allowing for charging while driving. The cost-effectiveness of CAT depends on the electrification of major highway corridors and the widespread adoption of electric trucks. Key barriers include high initial infrastructure costs with uncertain returns if uptake is limited, and potential inadequacies in transmission and distribution capacity in remote highway areas. Additionally, real-world pilots are more common in Europe, where freight distances are shorter compared to Canada and Ontario.

Other emerging technologies for Ontario's clean energy future

Several emerging fuels and technologies are expected to play a role in decarbonizing or offsetting hard-to-abate sectors.

- **Pyrolysis for biochar production:** Pyrolysis is the thermal decomposition of organic matter in the absence of oxygen, producing biochar, bio-oil, and syngas. Slow pyrolysis is a simple and cost-effective method for carbon capture and sequestration compared to conventional CCS methods. Biochar, a stable carbon-rich byproduct, is highly porous and primarily used for soil amendments and long-term carbon sequestration. It is also utilized as activated carbon in the automotive industry.

At time of writing, there is no industrial biochar production for carbon sequestration in Ontario. Biomass feedstock supply is limited by existing agricultural and forestry practices, impacting availability and cost. Developing robust supply chains and optimizing feedstock processing methods are essential to ensure a steady and affordable biomass supply for pyrolysis and improve cost-effectiveness.

- **Hydrogen:** clean hydrogen technologies for industrial applications, including electrolyzers, turbines, and boilers, are expected to play a key role in decarbonizing hard-to-abate sectors and applications. The lack of hydrogen infrastructure and the high costs associated with production and storage are significant barriers.
- **CCS and other negative emission technologies (NET)** (direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS)), are expected to play a key role in addressing GHG emissions from hard-to-abate sectors. However, they are characterized by high uncertainty and low technological readiness.

SECTION 5

5. The Pathways

5.1 Introduction: Modelling Cost-Effective Pathways

This section summarizes key results and insights from modelling cost-effective pathways to identify the least-cost trajectories for Ontario to achieve net-zero GHG emissions in 2050.[31] This modelling represents the core component of the study, leveraging an integrated energy system optimization model to find the least-cost pathways while respecting resource limitations and energy and climate policy objectives.

Specifically, this analysis sought to answer three key questions:

1. **GHG Emission Reductions:** Where will GHG reductions come from?
2. **Energy Demand:** How will energy demand change in key sectors and for key fuels?
3. **Energy Supply:** What resources will be used to supply Ontario's future energy needs?

These IPs reflect plausible future pathways for Ontario's energy system under different market and policy conditions, including one business-as-usual, including committed policies, pathway (the reference case integrated pathway, or REF IP), and ten pathways with a constraint of net-zero GHGs in 2050 (NZ IPs).

The results presented in this report are largely focused on the REF IP and the NZ50 IP. Insights from other IPs and SAs are presented where notable trends that deviate from REF IP or NZ50 are observed. In general, the H2+ IP is not analyzed in this report unless specifically noted because it does not test a plausible future under current conditions but rather looks at where hydrogen uptake would occur *if* there were a significantly larger amount of cost-effective supply. For the list of IPs and SAs and their abbreviations, see Table 1-1 and Appendix B.

This section summarizes key highlights and findings from Deliverable 3: Cost-Effective Pathways (Main Analysis) and Deliverable 4: Abatement Cost Curves. For further details, readers can refer to Deliverables 3 and 4.

[31] For most IPs and SAs, unless otherwise specified, the GHG constraint is based on National Inventory Report (NIR) scope.

Modelling Approach: Key Considerations and Caveats

NATEM, as an optimization model, provides the least-cost system solution under a given set of constraints. Results from this study for all pathways (including REF) **should not be interpreted as forecasts, rather they represent least-cost solutions based on cost optimized pathways,** which are not necessarily the most likely outcomes. They can be interpreted as projections of what may happen in a given scenario, under certain conditions. The modelling uses relaxed market shares and there is limited consideration for market barriers or economically irrational decisions.

As an economy-wide optimization model, there are inherent trade-offs that must be made in the complexity and granularity of the modelling, the time horizon and time periods resolved, and the solving time of the model. NATEM is one of the most technologically rich models of the energy system and it is very detailed in its representation of the energy sector. To solve such a model over a long time horizon requires selection of sub-annual time periods. In this study, a time period definition of 16 sub-annual time periods was used. More granular time modelling (e.g., at hourly level) was out of scope. Given the time period granularity and agreed upon scope of the study, assessing electricity system reliability and operability was also outside of scope and will need to be conducted to better understand electricity supply requirements. Nevertheless, modelling constraints are used where possible to represent certain operational constraints.

In terms of spatial granularity, NATEM models the 13 Canadian jurisdictions as independent regions. In this study, results are presented for Ontario, while the model was run for all Canadian jurisdictions to ensure that trade flows and other interactions are well represented nationally. There are limitations associated with modelling Ontario as a single region, particularly when it comes to electricity and gas T&D infrastructure that is largely dependent on spatial distribution of production and consumption. While more refined spatial disaggregation is possible, this typically implies greater complexity and longer solving time and was not in the scope of this study.

Given these factors and other study limitations, additional analysis beyond the study will be needed to assess the feasibility and specific requirements for a plan along with other specific implications for long-term planning. The study is a first-of-a-kind study for Ontario and should be considered a starting point for discussions and future work regarding the future of Ontario's energy systems. For example, future work building on this study should include detailed analysis of resource adequacy and transmission and distribution requirements.

It should also be noted that costs associated with investments made in 2021 or earlier, including any amortized costs that would extend into the future, are not modeled.

Due to data availability, NATEM is calibrated using 2016 to 2021 data. The modelled year 2022 and onwards are modelled, so actual (historical) numbers for 2022 may differ from the modelled results.

For additional detail on key considerations and caveats related to the modelling approach, please refer to Deliverable 3: Cost-Effective Pathways.

5.2 GHG Emissions

Overview

If all the actions implied by the modelled policies in the REF IP materialize,[32] Ontario is on track to reach its 2030 GHG emissions target (e.g., 30% reduction relative to 2005 levels) (Figure 5-1). However, in the REF IP, a significant gap remains to achieving net-zero emissions in 2050, and GHG emissions start to increase post 2040 as the increase in final energy consumption in the province outweighs the impact of the modeled policies; in particular, as some key policies are phased out post-2030 or have decreasing effect (e.g., investment tax credits (ITCs), and the federal carbon price in real dollars).

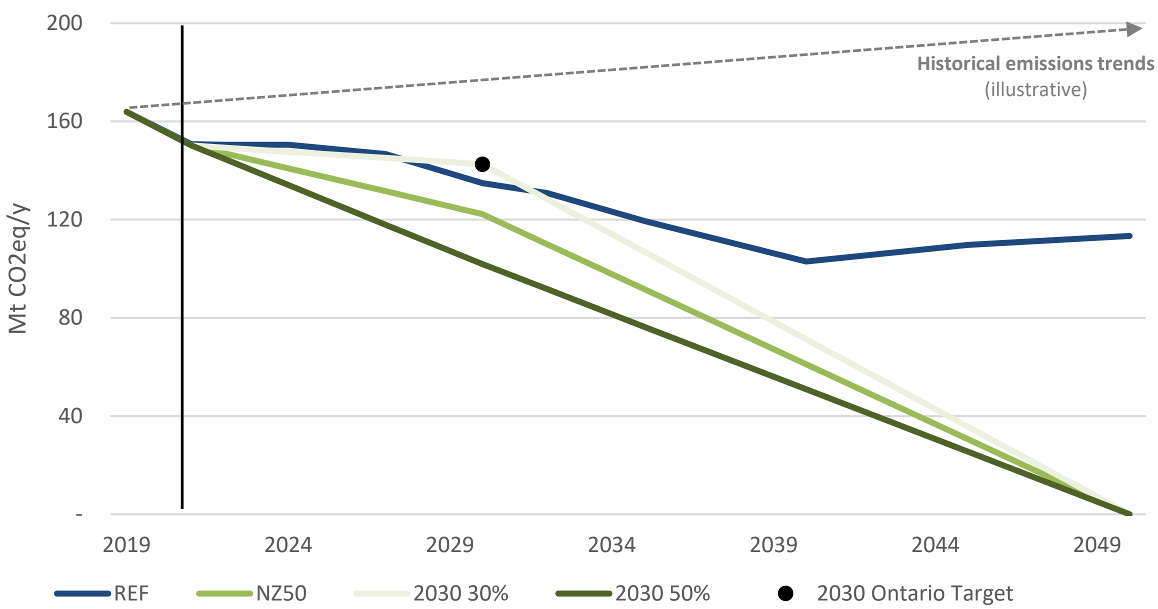


Figure 5-1. Annual GHG emissions (Mt CO2eq/y) from 2019 to 2050 for select integrated pathways (Economy-wide GHG emissions covered by the NIR)[33]

[32] The reference case should not be interpreted as a no-action pathway. It assumes a significant level of action, as per the modeled announced federal and provincial policies and additional restriction on new natural gas generation. Similar to the decarbonization pathways, it has limited consideration of market barriers and irrational economic decisions.

[33] Throughout report, "Economy-wide GHG emissions covered by the NIR" exclude GHGs from international aviation and marine. See Deliverable 3, Appendices E and F for emissions including international marine and aviation and for emissions by greenhouse gas.

GHG Emissions by Sector

To close the gap and achieve net-zero GHG emissions in 2050, there is a need for significant emissions reductions across all sectors, as well as the introduction of negative emission solutions after 2030 to compensate for remaining GHG emissions in sectors where full decarbonization is challenging or costly. Specifically, in the NZ50 IP (Figure 5-2):

- **Residential and commercial sector GHG emissions are completely eliminated in 2050.**
- **Transportation sector GHG emissions are reduced by 90%** compared to 2019.
- Over **50% of remaining GHG emissions in 2050 are from the agriculture sector**, driven by non-energy emissions related to soil management, fertilizer application and livestock.
- To offset the GHG emissions that do remain in 2050, the **industrial and electricity sectors become net-negative emitters**, through the use of CCS and NETs, including bioenergy with carbon capture and storage (BECCS) and biochar production (whose negative emissions are allocated to the industrial sector), **and DAC is used**.

  Using an optimistic estimate of Ontario's geologic sequestration potential, at the 2050 rate of sequestration, if all geologically sequestered CO2 was done within Ontario, the province's capacity will be exhausted between 2074-2081 across NZ IPs and SAs, except in CCS- and CCS- NZ-, which run out in 2233 and 2232 respectively. To maintain net zero in the long-term, while waiting for other technologies to develop, it may prove more cost-effective to preserve geologic sequestration space for the longer term and pursue earlier electrification and decarbonization efforts. The IPCC has also indicated that to stabilize global temperatures, or in a scenario where global temperature overshoots 1.5^{o}C of warming, the world would need to become carbon negative to maintain temperatures in the long term or even bring temperatures back down. If Ontario were to use carbon sequestration to become carbon negative, either more space needs to be conserved, or space will run out faster.

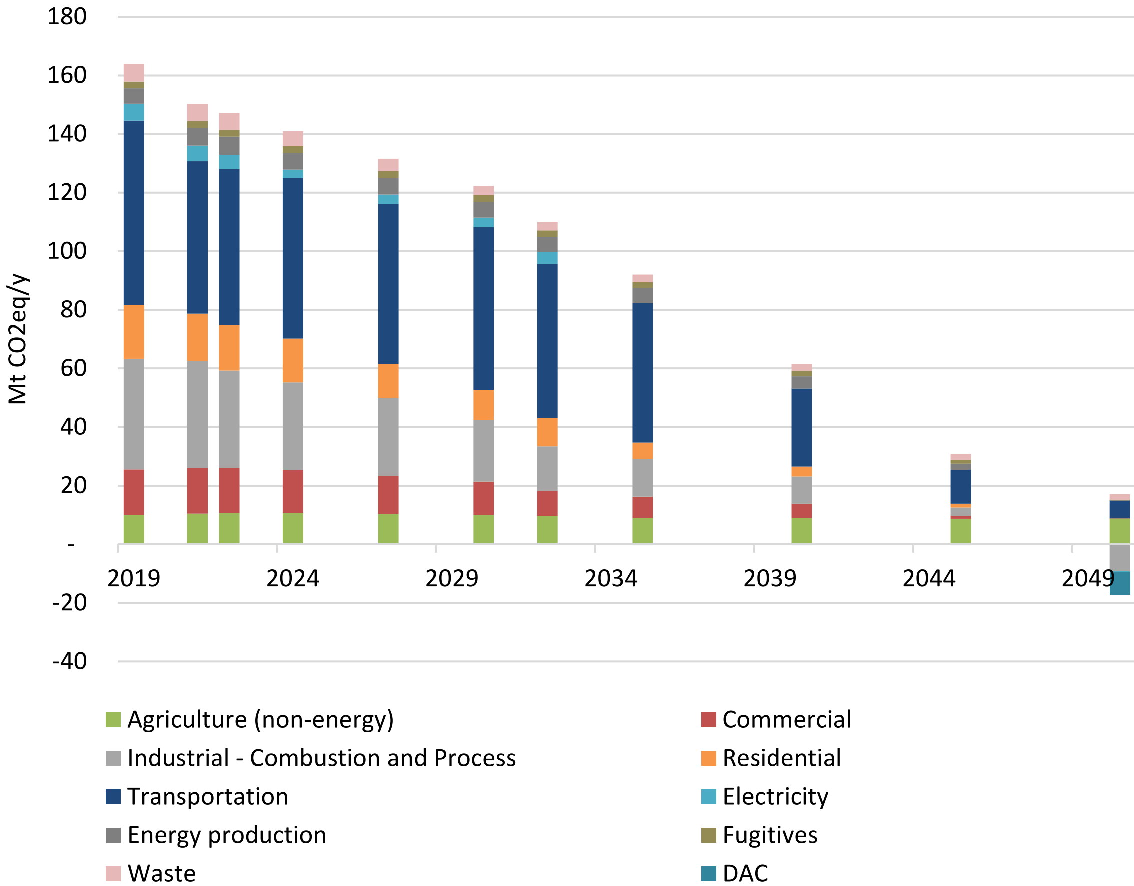


Figure 5-2. Total annual GHG emissions by sector (Mt CO2eq/y) from 2019-2050 for the NZ50 IP (Economy-wide GHG emissions covered by the NIR)

The Impact of Abatement Cost on GHG Emissions Reductions by Sector

Abatement Cost Curves (ACCs) can highlight insights into the cost-effectiveness of abatement in various sectors and of various measures, and their potential impact on achieving GHG targets. All measures up to a desired amount of GHG reductions, e.g. net zero in 2050, must be implemented; if certain measures are not implemented, more expensive alternatives are required to meet the desired GHG reductions.

GHG emissions reductions relative to the reference case required to get to net-zero in 2050 can be broken down into progressive phases, including:

Phase 1, the first step of the curve;

Phase 2, between the first step and 50% of the IP end-point GHG emissions reductions;

Phase 3, between 50% and 80% of the IP end-point GHG emissions reductions;

Phase 4, between 80% and 100% of the IP end-point GHG emissions reductions;

For analysis on **Phase 5** (showing measures beyond the end point), please see Deliverable 4.

The REF IP, which served as the starting point for the ACC curves, **already incorporates substantial GHG emissions reductions in 2050 compared to 2019,** notably in light-duty transportation, due to ambitious policies modelled as well as the low total cost of ownership of EVs, as well as in the buildings sector due to energy efficiency, ASHPs, district energy systems (DES) and ground-source heat pumps (GSHPs).

Phase 1: Low-cost abatement opportunities in industry and agriculture. Initially, low-cost solutions such as reducing enteric fermentation and improving manure and soil management in agriculture, introducing biochar production and industrial process CCS, and increasing wind capacity while reducing natural gas generation (without CCS) in the electricity sector are most cost-effective.

Phase 2: Gradually increasing GHG emissions reductions across all sectors other than agriculture. Non-energy agriculture GHG emissions stabilize, but gradually increasing GHG emissions reductions are achieved across all other sectors as the abatement cost increases. Additional decarbonization in the residential and commercial sectors occurs relatively early on (at lower abatement costs), with the increasing use of DES. Electricity generation from natural gas (without CCS) continues to steadily decrease and generation from increasing wind and solar capacity takes its place. Water heating electrification, commercial dual heating systems and the use of RNG are also introduced.

Phase 3: Further GHG emissions reductions in industry and transportation. At this stage, the electricity and buildings sectors are largely decarbonized, and there are fewer abatement opportunities in these sectors. BECCS hydrogen production, hydrogen use in industry, and hydrogen turbines for electricity generation are introduced materially in this phase.

Phase 4: Higher-cost solutions, including DAC. The remaining 20% of NZ50 IP emissions reductions are achieved largely through DAC, as well as deeper decarbonization across all sectors, with industrial decarbonization being another major contributor.

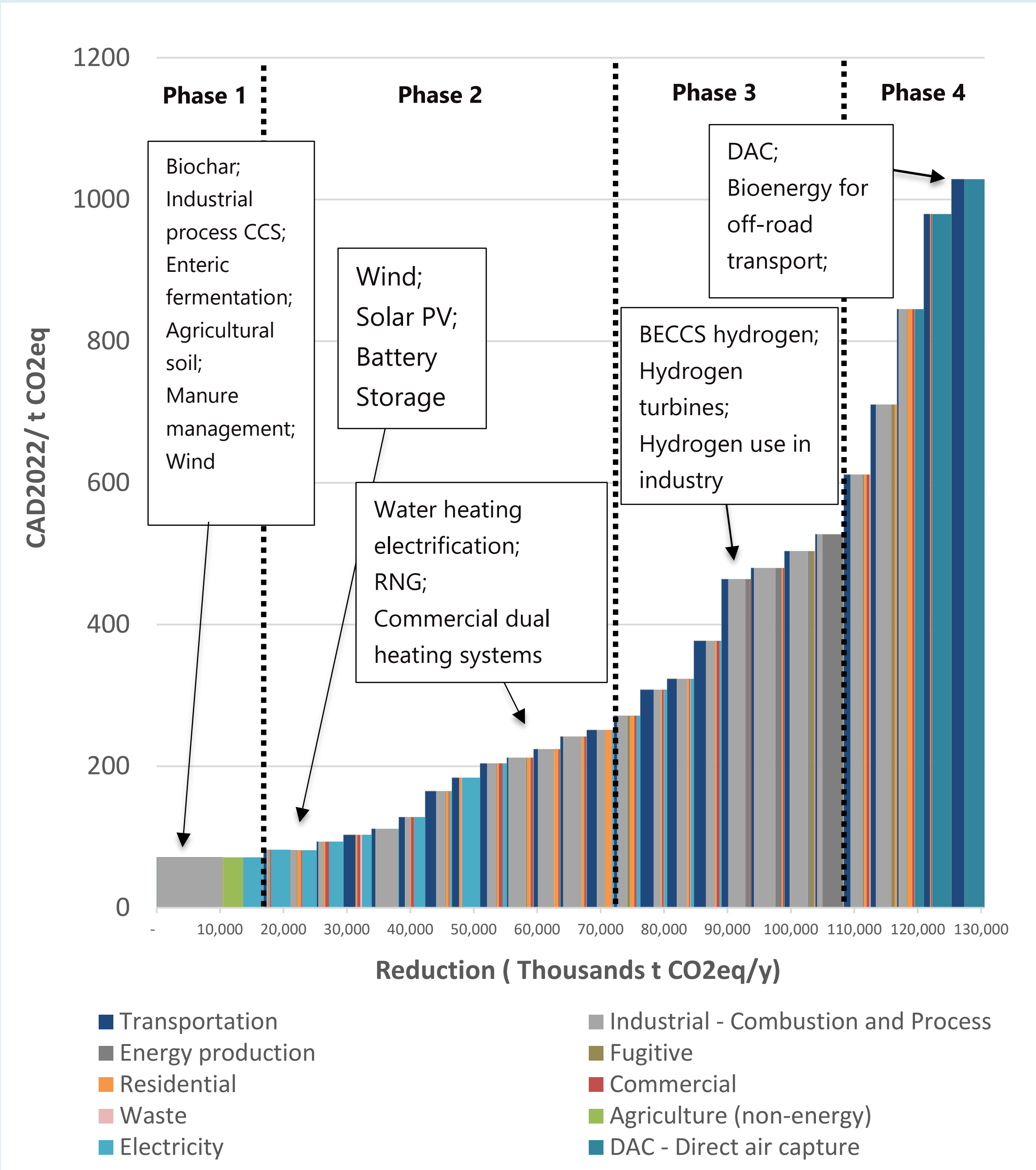


Figure 5-3. 2050 ACC (CAD2022/t CO_2eq) with GHG emissions reductions by sector (t CO_2eq/y) (NZ50 IP)

The Net-Zero Effect

Certain solutions which reduce, but do not eliminate, GHG emissions – such as dual fuel space heating systems using fossil natural gas and production (and use) of blue hydrogen – appear cost-effective at intermediate abatement costs. However, as the marginal abatement cost escalates moving towards net-zero, widespread use of these solutions may not remain economically viable compared to alternatives, as the remaining GHG emissions become costly to manage.

Note that the sector-level analysis presented for ACCs only looks at decreases in GHGs from one step of a GHG constraint to the next; the increases are ignored. So, the total GHG reductions in the sector-level graphs exceed the total of economy-wide GHG reductions.

5.3 Energy Demand

Overview

While fossil fuels currently account for the majority of Ontario's final energy consumption, **across NZ IPs, electricity becomes central to Ontario's energy system,** accounting for the majority (56-64%) of final energy consumption in 2050 (Figure 5-4). Other key takeaways for Ontario's final energy consumption across NZ IPs include:

- **Energy consumption decreases between 2019 and 2050**, despite increasing population, GDP, and demand for energy services. This is partly driven by electrification (electric technologies can be greater than three times more efficient than the equivalent fuel-based technology), as well as other energy efficiency and conservation measures, such as improved building envelopes.
- **Clean fuels such as liquid biofuels, renewable natural gas (RNG) and clean hydrogen[34] are used strategically** in sectors where electrification is expected to be more challenging or costly and make up 13-19%[35] of Ontario's final energy consumption combined in 2050.

[34] Throughout the report, whenever hydrogen is referred to as "clean hydrogen", this is in reference to electrolytic, blue, or biogenic hydrogen. Grey hydrogen (produced from natural gas without CCS) is not considered "clean".
[35] Comprises solid, liquid and gaseous biofuels, hydrogen and synthetic fuels.

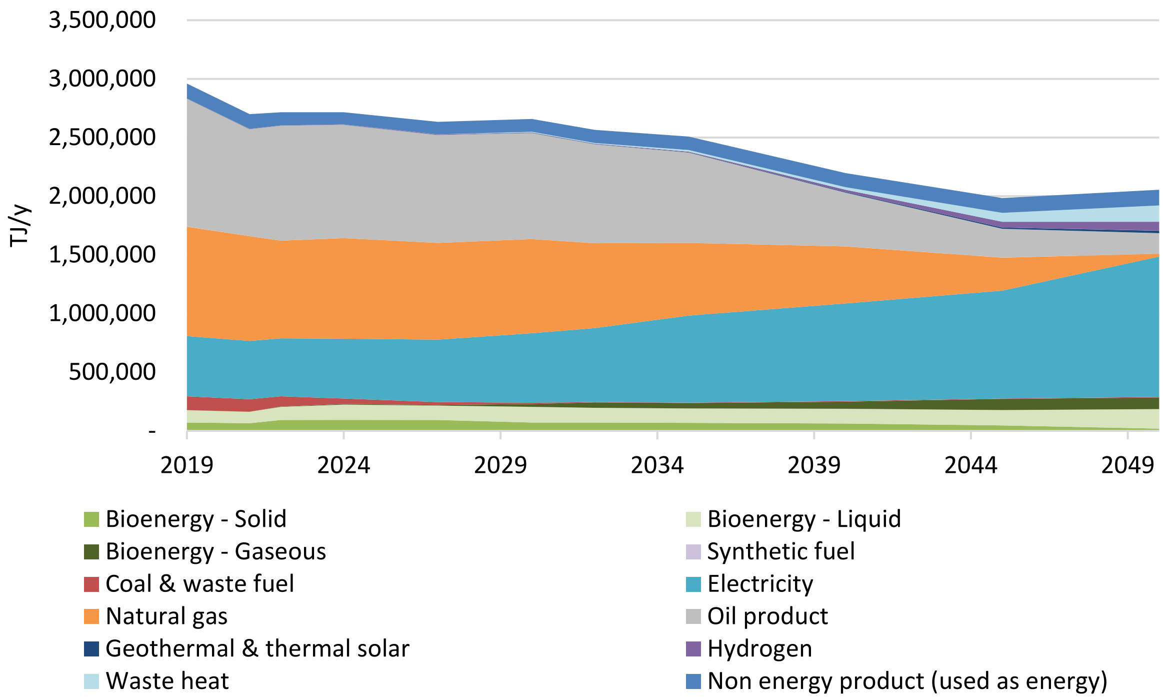


Figure 5-4. Final energy consumption (TJ/y) by fuel type from 2019 to 2050 for the NZ50 IP

Buildings

Across all IPs including REF, buildings are largely electrified, and electricity accounts for the vast majority (62-80%, depending on the pathway) of final energy consumption in 2050 (Figure 5-5). This is driven by electrification of space heating and water heating in both residential and commercial buildings – electric heat pumps (including air-source heat pumps, ground-source heat pumps, and dual systems[36]) supply more than 50% of Ontario's useful space heating demand in 2050 in all IPs including REF.[37] Other notable trends for NZ IPs include:

- **Final energy consumption decreases significantly between 2019 and 2050**, driven by electrification, improved envelopes for both new and retrofit buildings, and controls.
- **DES is another key pathway for decarbonizing space heating**,[38] accounting for 35-37% of residential and commercial space heating across NZ IPs.

[36] Dual systems include an air-source heat pump with a gas fueled backup system. The air-source heat pump provides the majority of the heating, but the system switches to the gas backup when outdoor air temperatures are very low. The gas can be natural gas, RNG or hydrogen blend.
[37] Useful space heating demand refers to the output heat energy required to fulfill space heating needs.
[38] It should be noted that while the modelling illustrates significant potential for district energy systems, future proximity of district energy system (DES)-compatible areas and SMRs is challenging to predict, and achieving a high penetration of DES will require careful coordination and planning.

- **Waste heat and GSHPs are leveraged for space heating in DES.** [39] By 2050, across all NZ IPs, inexpensive waste heat from SMRs supplies 32-37% and 33-37% of annual useful space heating demand in the residential and commercial sectors, respectively. In earlier years, and in the REF IP, GSHPs are also used.
- The use of fossil natural gas is eliminated – however, **RNG *may* play a minor but strategic role in mitigating peak impacts of electrification through use in dual systems. However, death spiral effects[40] on the natural gas system were not modelled and could impact the feasibility of maintaining the natural gas network.**

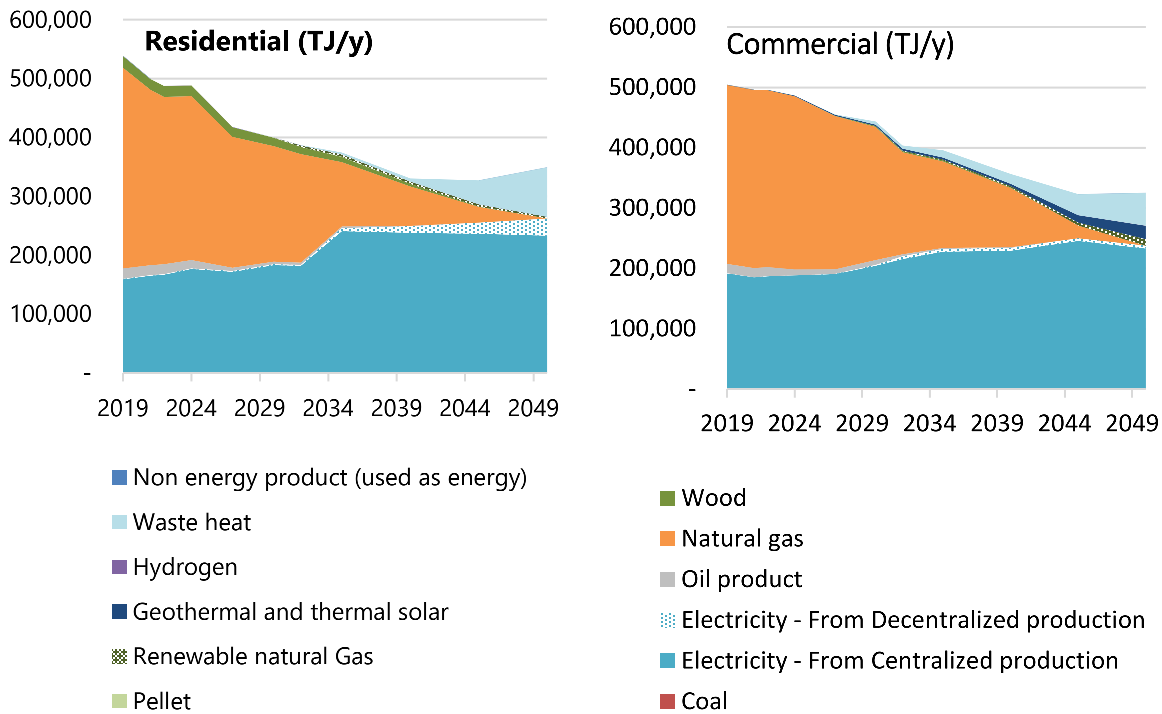


Figure 5-5. Final energy consumption (TJ/y) by fuel type from 2019 to 2050 for the NZ50 IP in the residential (left) and commercial (right) sectors

Transportation

Across all NZ IPs, electrification and the use of biofuels emerge as key pathways to decarbonization of the transportation sector, accounting for 41-50% and 14-22% of final energy

[39] Heating from DES can be supplied by a variety of sources, however, to be decarbonized waste heat should come from electric heat pumps or clean fuels. The modelling mainly sees GSHPs and, in later years in NZ IPs, waste heat.
[40] Death spiral effects refer to a decline in gas consumption and connected customers, leading to higher costs for those remaining and resulting in even higher and faster disconnections.

consumption in 2050, respectively[41] (Figure 5-6). The use of some fossil-based fuels also remains in sub-sectors which are harder or more costly to decarbonize, such as aviation and off-road. Notably, final energy consumption in the transportation sector decreases significantly between 2019 and 2050, even as annual passenger-kilometers and annual tonne-kilometers travelled continue increasing. This is driven by the much higher efficiency of electric drivetrain vehicles (~3-4x) compared to internal combustion engines.

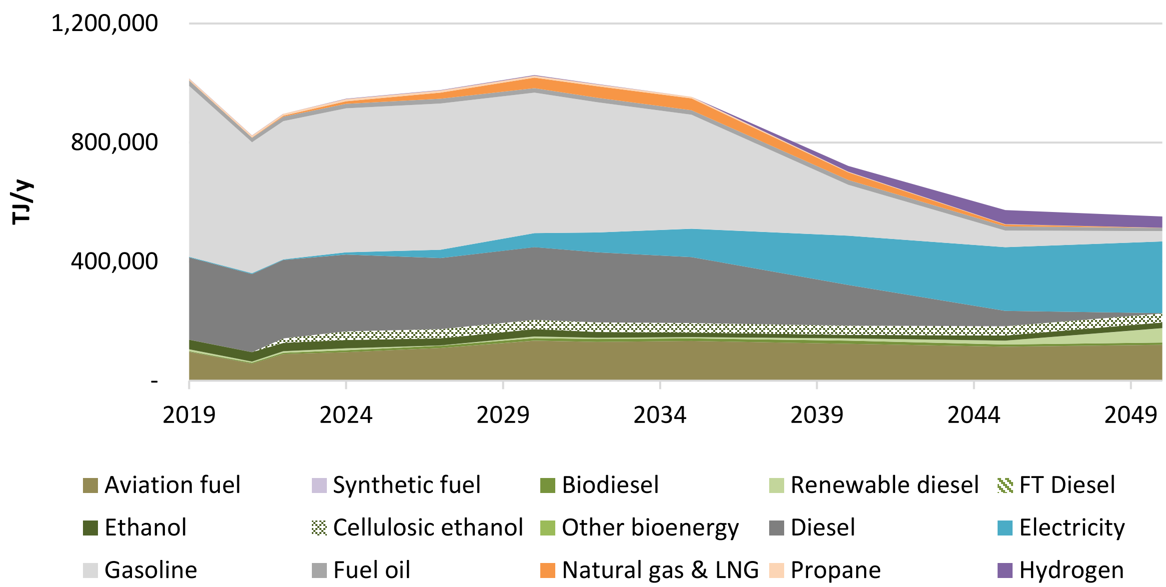


Figure 5-6. Final energy consumption (TJ/y) by fuel type from 2019 to 2050 for the NZ50 IP

The transportation sector includes many highly diverse sub-sectors and end-uses, and the extent of and pathway to decarbonization varies accordingly. Big-picture takeaways for key sub-sectors and end-uses include:

- **Light-duty road transportation is fully electrified in 2050, even in the REF IP,** for cars, passenger light-trucks and freight vehicles. This is driven by policy (federal ZEV mandate), as well as the declining total cost of EV ownership.[42]
- **Heavy-duty freight shifts towards battery electric, catenary electric and hydrogen** vehicles, with the split sensitive to the assumptions across different IPs.
- **Aviation is not decarbonized in most IPs,** but the use of synthetic fuels emerges as a potential pathway in IP/SAs requiring deeper decarbonization.
- **Buses are predominantly electrified in NZ IPs,** and hydrogen also plays a role.

[41] This excludes the H2+ IP. See section 1.2.
[42] The only form of light-duty transportation which is not fully electrified across select IPs and SAs (REF, ELC-, NZ50 NZ+) is motorcycles.

Other transportation modes – including rail, marine, and off-road transport – leverage a mix of electrification, biofuels and hydrogen.

Industry

Across NZ IPs, **the industrial sector is largely electrified**, and electricity accounts for the largest share of final energy consumption in 2050 (42-49% excluding the H2+ IP) (Figure 5-7). However, certain industries and processes are more challenging or costly to electrify – therefore, **there is also an important role for clean fuels – primarily renewable natural gas (10-15% of final energy consumption in 2050) and some hydrogen (3-9% of final energy consumption, excluding the H2+ IP).**[43] Some limited use of fossil fuels remains where lower-emitting alternatives are uneconomic or unavailable.

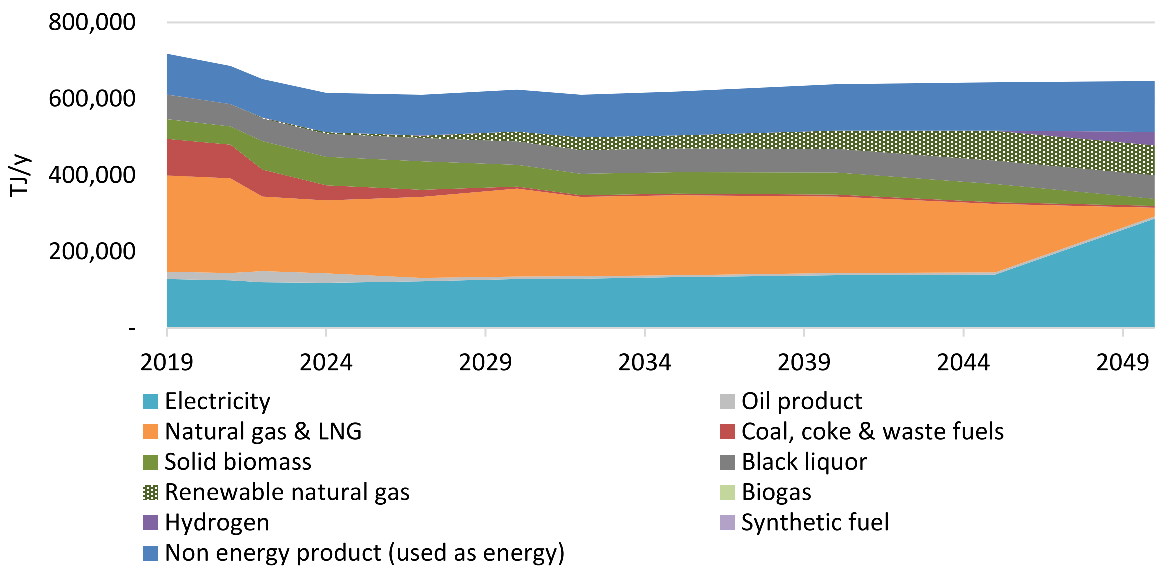


Figure 5-7. Final energy consumption (TJ/y) by fuel type in the industrial sector from 2019 to 2050 for the NZ50 IP

5.4 Energy Supply

In response to the changes in energy demand highlighted in the earlier sections, achieving net-zero in 2050 across **NZ IPs will require Ontario's energy supply to evolve to meet these shifting demands.** In particular, a significant increase and shift in electricity supply is needed to meet the growing demand for electricity as electrification plays a pivotal role in decarbonization of key end-uses in the transportation, buildings and industrial sectors. Additionally, the

[43] Hydrogen is predominantly used as pure hydrogen - blending in natural gas network for the industrial sector is negligible. The modelling considers a 5% (by energy) cap on hydrogen blending in natural gas pipelines.

contribution of clean fuels, including clean hydrogen and biofuels such as liquid biofuels and RNG, also increases.

Electricity

To meet the increase in demand for electricity (to 315 to 455 TWh/y in 2050), **Ontario's electricity supply will need to expand significantly – on the order of double to triple today's system across all NZ IPs**– to power the province's economy. In 2050, 87-115 GW of installed capacity will be needed to meet the province's electricity demand in the NZ IPs, (e.g. Figure 5-8 shows the NZ50 IP). Supply also increases significantly in the reference case (to 1.5x from 2019 to 2050), to meet the corresponding increase in demand (to 1.5x from 2019 to 2050).

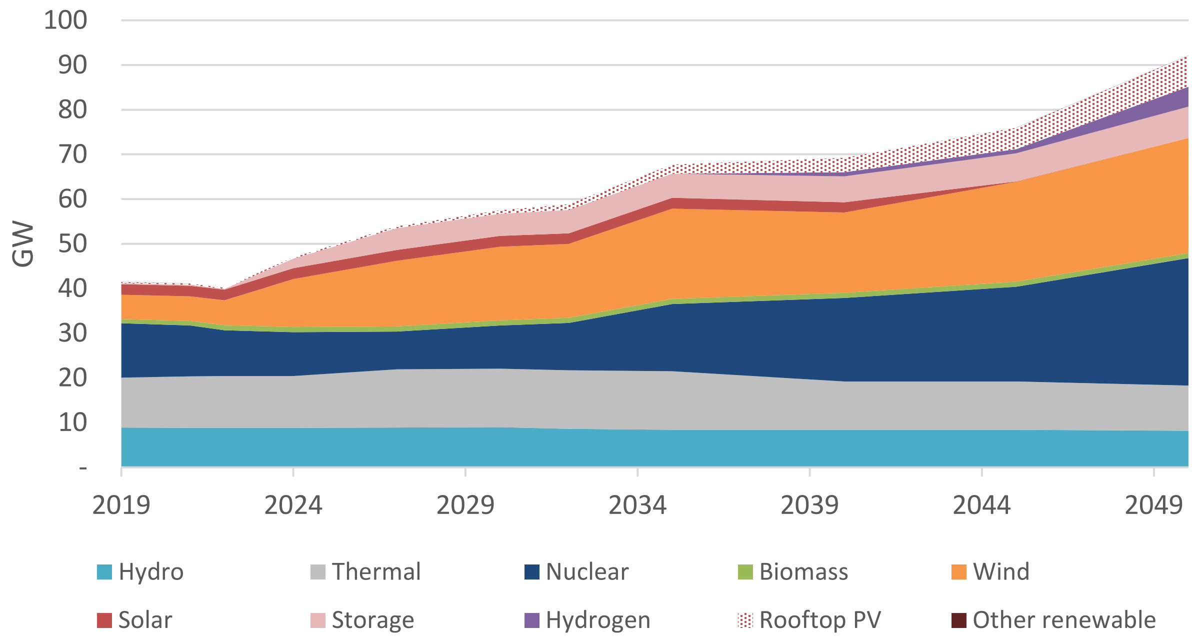


Figure 5-8. Installed capacity (GW) by technology in 2019 to 2050 for the NZ50 IP

The growth in electricity supply in NZ IPs is largely dominated by growth in wind and nuclear capacity, 12-26 GW and 12-31 GW respectively, between 2019 and 2050. Growth in conventional and advanced nuclear (GEN III+) capacity is driven by the capacity additions planned under the Powering Ontario's Growth initiative – however, additional growth in SMRs is significant, with 8-27 GW of added capacity over and above what is planned under Powering Ontario's Growth. Since SMRs only reach the required economies of scale in later years, the addition of wind capacities mid this decade is a key contributor to increasing supply. Growth in SMRs is moderate until the 2040's. While each technology offers unique benefits, across modelled IPs, there is some trade-off between the magnitude of wind versus SMR deployment – for example, if SMR cost declines are less significant, wind capacity additions may be more significant.

Beyond wind and nuclear, a notable growth in rooftop solar is observed in NZ50. Additionally, there is 7 GW of electricity storage (both batteries and pumped hydro) in 2050 to support renewables integration and/or peak needs. In 2050, the supply mix also includes a notable portion of the existing natural gas fleet as well as new hydrogen capacity to meet resource adequacy needs.

The Role of Onshore Wind and SMRs

Both wind and nuclear (SMRs) are expected to play a key role in Ontario's energy transition across all NZ IPs and SAs. Each technology offers unique benefits that are essential for an affordable and reliable emissions-free electricity system. No single generation technology can cost-effectively ensure grid stability and energy and supply resource adequacy. Instead, a diverse mix of technologies – including wind, SMRs, and others identified in the modelling results – is essential to achieve these goals in a cost-effective manner.

Wind energy, while variable, is a cost-effective option for energy production.

Despite the higher cost and uncertainty associated with SMRs, their ability to provide consistent, reliable baseload power with a high capacity factor and guaranteed contribution to peak demand mean that this technology is well-suited to meeting baseload needs.

The modelling results show that the **complementary nature of wind and SMRs implies that both are necessary for a resilient and cost-effective energy transition in Ontario.** However, the relative contributions of wind vs. SMRs to the overall mix will depend on assumptions, for example, regarding the evolution of technology costs, capacity factor and contribution to peak demand.

As an illustration of uncertainty, in 2050, the central per kW cost estimate for wind is CAD 2022 $1,142, with a range of approximately +/- 20% (from CAD 2022 $879 to CAD 2022 $1,352). On the other hand, the central per kW estimate for SMRs is approximately CAD 2022 $9,500,[44] with a range of +/- 40% (from approximately CAD 2022 $5,700 to CAD 2022 $13,300).

As an emerging technology, the cost trajectory of SMRs is less certain, which leads to some variation in deployment across modeled pathways. In contrast, onshore wind has a more predictable and narrower cost range. This comparison highlights the importance of technology assumptions for cost-effective pathways.

Bioenergy

Across NZ IPs, Ontario leverages a diverse mix of biomass feedstocks to fulfill the significant growth in demand for biomass. There is increased utilization of forest residues and roundwood, and Ontario also begins to leverage the significant potential of agricultural residues and source-

[44] With some variation depending on the type of SMR technology.

separated organics (Figure 5-9). There is also continued use of landfill gas from 2019 to 2050, and limited use of dedicated fast-growing trees and crops after 2040. The use of corn, wheat, soy and canola-based feedstocks is **already near the maximum sustainable potential in 2019**, which is limited considering these feedstocks are also in competition for land use with food crops, therefore the growth in demand for biomass is primarily fulfilled by other feedstocks.[45]

Across all NZ IPs, almost all biomass supply potential is used in 2050. This includes 97-98% of forest biomass supply, 100% of crop residue supply, and 100% of the potential for dedicated fast-growing trees and crops. Only industrial residue and corn and wheat supplies are not used up to, or near, their max potential.

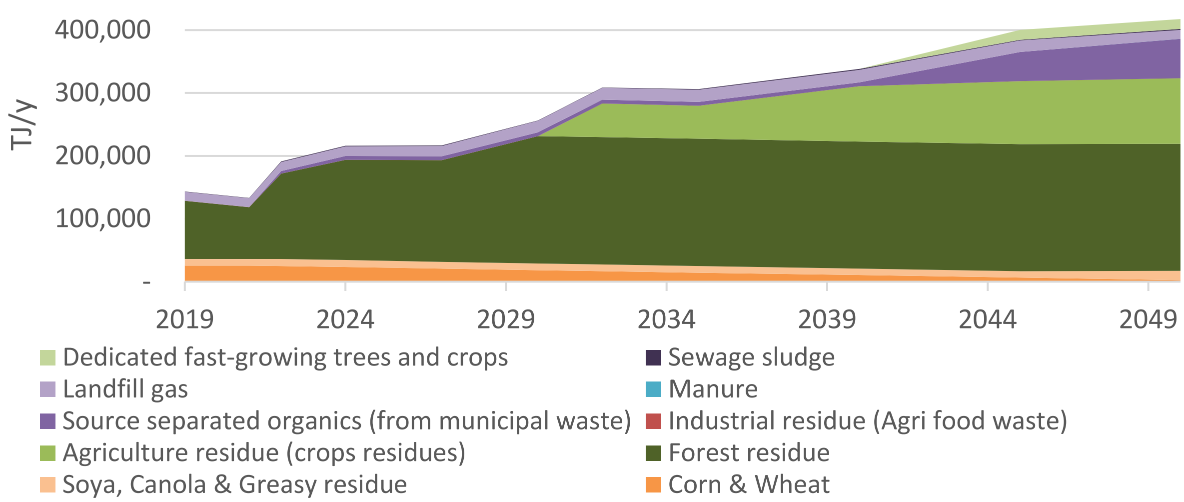


Figure 5-9. Bioenergy feedstock supply (TJ/y) in 2019 to 2050 for the NZ50 IP

Hydrogen

Across NZ IPs, hydrogen production increases significantly, particularly post-2035 (Figure 5-10). Initially, "blue" hydrogen production technologies (production from natural gas with CCS) dominate hydrogen production, ramping up significantly between 2035-2045, and production from natural gas without CCS is gradually phased out. In later years (post-2045), production from biomass with carbon capture and storage (BECCS) also supplies a portion of hydrogen demand, and BECCS production also contributes to the generation of negative emissions to meet the net-zero in 2050. Provincial imports also ensure Ontario's supply of hydrogen meets the demand in 2050 across the majority of NZ IPs.[46]

[45] In this report, biomass feedstock supply refers to potential supply used for energy, for example, it excludes food production and biomass used for other products.

[46] Except in H2+ (which is an outlier, see section 1.2) and BIO+, where additional availability of biomass leads to increased BECCS production.

Across modelled NZ IPs, hydrogen pathways exhibit some sensitivity to the modelled assumptions – for example, if electrification conditions are favourable (ELC+), the production of blue hydrogen is eliminated (and overall supply and demand for hydrogen is decreased). On the other hand, in pathways where deeper GHG emissions reductions are required (CCS- and CCS NZ-) and there is a need to produce synthetic fuels, electrolytic hydrogen is produced.[47]

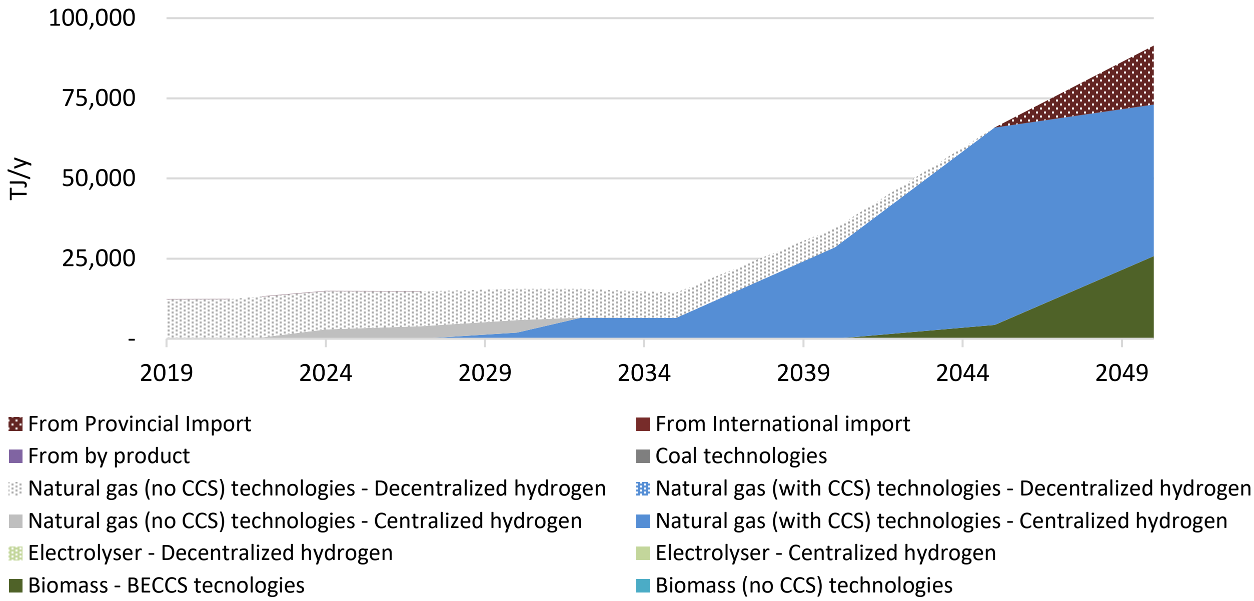


Figure 5-10. Hydrogen production (TJ/y) by technology and imports in 2019 to 2050 for the NZ50 IP[48]

The production of electrolytic hydrogen is absent (Figure 5-10) in 2050 from the majority of IPs including REF, apart from the exceptions noted above. This is likely due to the combined impact of several factors, including: (1) due to significant increase in electricity demand in other sectors, significant build-out of electricity generation capacity is already required, and electrolytic hydrogen is electricity-intensive, which would put further pressure on the electricity system and require costly build-out of capacity; (2) the total efficiency (production and consumption) of electrolytic hydrogen is relatively low, making direct electrification of end uses more cost effective in many cases. However, it should also be noted that the long-term cost-effectiveness of blue hydrogen in a NZ IP will also likely depend on the capture efficiency, assumed to be 95% in the modelling. If this capture efficiency cannot be achieved, blue hydrogen may no longer be the most cost-effective option.

[47] Electrolytic hydrogen production is also seen in the H2+ pathway which, as mentioned, is an outlier (see section 1.2) and assumes a production tax credit for electrolytic hydrogen.
[48] Hydrogen supply includes hydrogen used as a feedstock, including for energy (e.g., synthetic fuels) and non-energy (e.g., fertilizer) applications.

SECTION 6

6. The Impacts

6.1 Economic Impacts

Net-zero by 2050 will require substantial investments in the electricity sector

Steering Ontario's economy onto a pathway to achieve net-zero in 2050 will require additional cumulative investments of CAD2022 $173B (in the NZ50 IP) beyond costs projected in the REF IP (Figure 6-1) from 2019 to 2050. Incremental investment will be primarily concentrated in the electricity sector, due to the high need for emissions-free electricity supply and transmission and distribution. The buildings sector will also require incremental investments to drive further electrification. Incremental investment in the transportation sector is relatively small, as current policies and cost trends already drive significant decarbonization of transportation in REF.

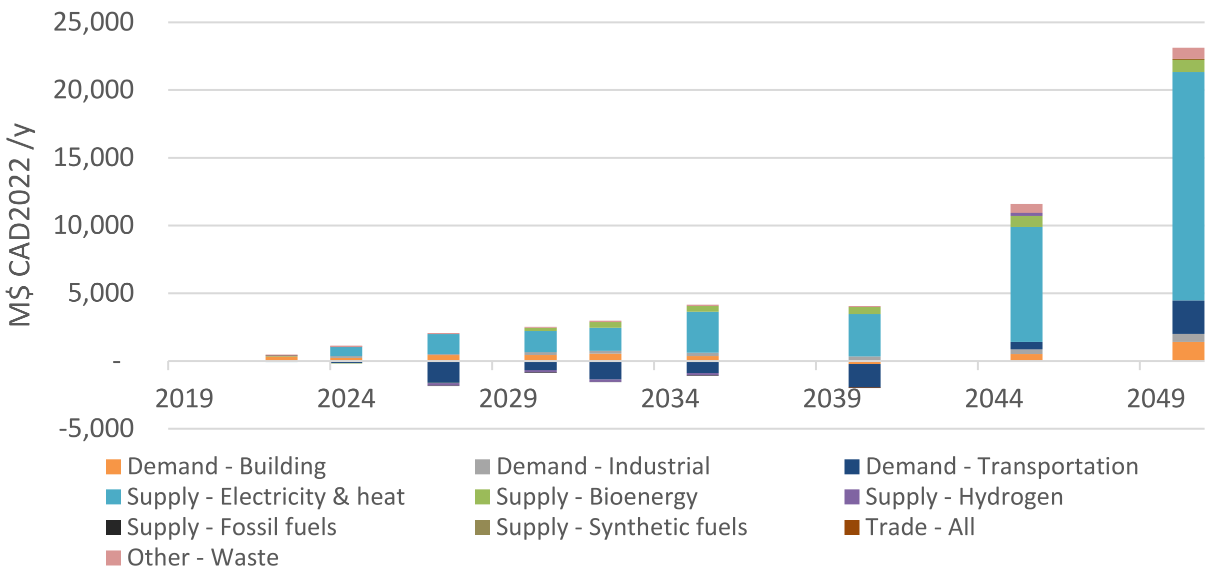


Figure 6-1. Annual incremental investment cost (M$ CAD2022/y) of the NZ50 integrated pathway compared to the REF IP in 2019 to 2050

This section summarizes key highlights and findings from Deliverable 3: Cost-Effective Pathways (Main Analysis) and Deliverable 4: Abatement Cost Curves. For further details, readers can refer to Deliverables 3 and 4.

Significant Reductions Can be Achieved at Lower Abatement Costs

The findings indicate that substantial GHG emissions reductions can be achieved at costs significantly lower than the end-point abatement costs. For example, in 2050, over 80% of the emission reductions achieved at the NZ50 IP endpoint can be achieved for 50% or less of the final abatement cost (CAD2022 $528/t CO2eq vs. $1,029/t CO2eq). The average marginal abatement cost required to reach the NZ50 end point is CAD2022 $355/t CO2eq. [49]

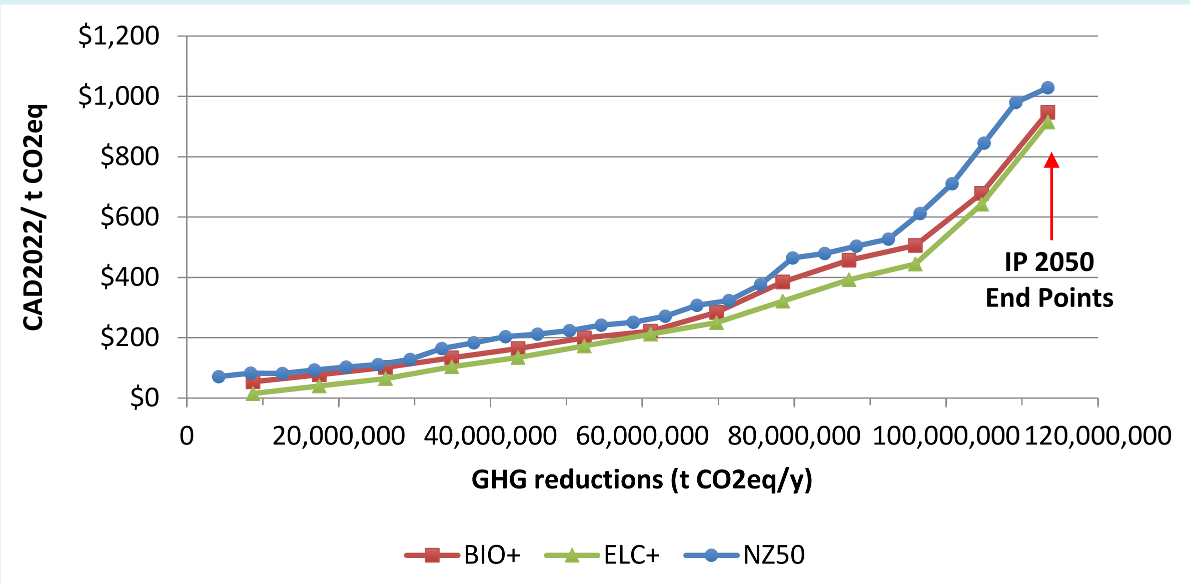


Figure 62. 2050 Abatement cost (CAD2022/t CO2eq) for different GHG emissions reductions (t CO2eq/y) relative to the REF IP (excluding points past net-zero-)

Energy and climate policies represent a minor impact on GDP

Incremental impacts of Ontario's energy transition on GDP will be 0.02-0.08 percentage points per year[50] lower in NZ IPs compared to REF, or between CAD2022 $0.4 and $1.2 billion per year in 2050 in absolute terms (Figure 6-3). Although fuels and energy technologies are used in all sectors, the share of GDP that is associated exclusively with energy services and goods is small. For example, the Ontario Energy sector (aggregate T016 that combines the North American Industry Classification System (NAICS) codes 211, 2121, 21229, 213111, 213118, 2211, 2212, 32411, 486) represents around 3% of the total Ontario GDP, while the energy labour force is about 5% in 2019.

[49] The actual (i.e., not marginal) average abatement cost is lower than the average marginal or total marginal abatement cost.

[50] Difference in average real annual growth (%/y) (2019-2050) between REF and NZ IPs

Therefore, the overall impact on provincial GDP and other global indicators (such as labour demand) from energy and climate policies is minor, although impact in individual sectors can be relatively larger.

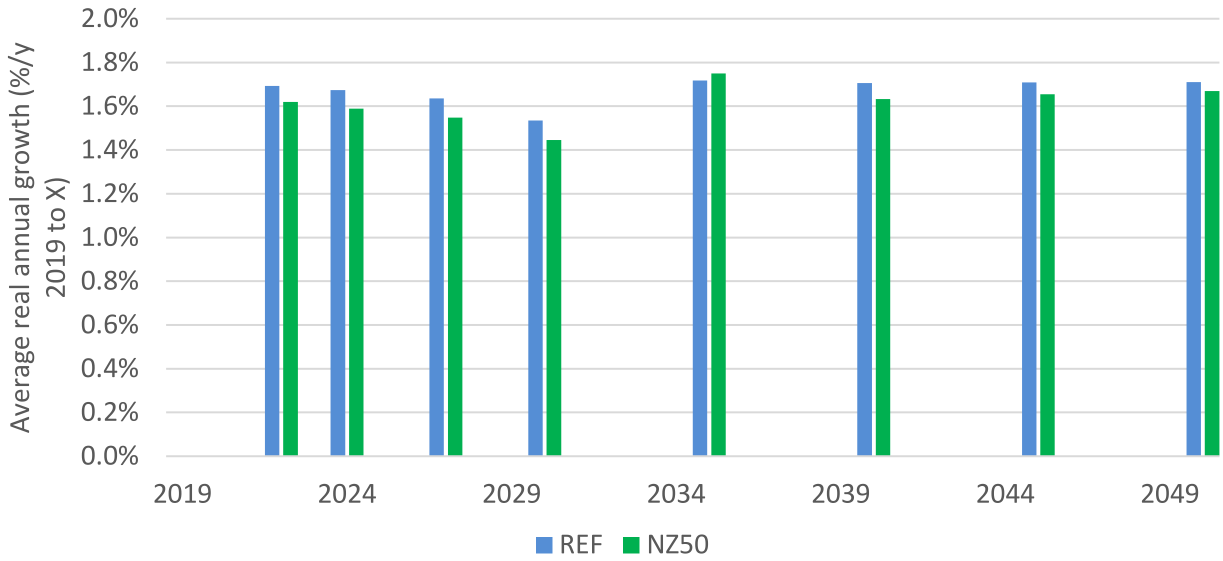


Figure 6-3. Average real annual GDP growth (%/y 2019 to X) in REF and NZ50

6.2 Household Impacts

Household energy bills are expected to decline

At a more granular level, **household energy bills are generally expected to decrease by 40-56% (or CAD 2022 214-304/month)** [51]between 2022 and 2050 across the REF IP and NZ IPs (as seen in Figure 6-4, which represents the "average" or total normalized monthly household energy cost in NZ50).[52] While the transition of Ontario's energy system towards net-zero may put upward pressure on electricity tariffs (due to the need for building out electricity supply capacity, for example), ultimately **households will still decrease the total amount they are spending on energy thanks to an overall reduction in energy consumption, driven by fuel switching and other energy savings.**

[51] Without OER, with legislated carbon price.

[52] The "average" or total normalized energy bill refers to the total cost of residential electricity and fuels (such as natural gas, gasoline, heating oil) divided by the number of households in the province.

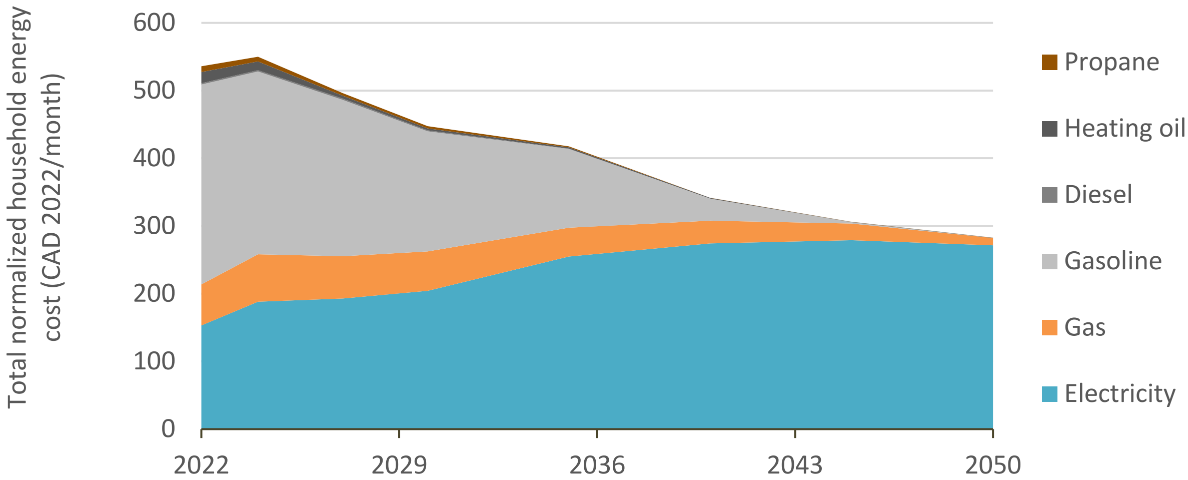


Figure 6-4. Evolution of normalized residential energy cost 2022 to 2050 for NZ50 IP without OER with legislative carbon price (HST, federal excise tax, provincial fuel tax, and the federal fuel charge are included)

The same decreasing trend is seen for "typical" household energy bills, defined for a household which uses the plurality (most common) technologies for space heating, water heating, vehicles and cooking. Typical household energy bills are expected to decrease by 15-31% (or CAD 2022 78-159/month) (Figure 6-5). Note that the modelled "typical" households may be different than specific households.

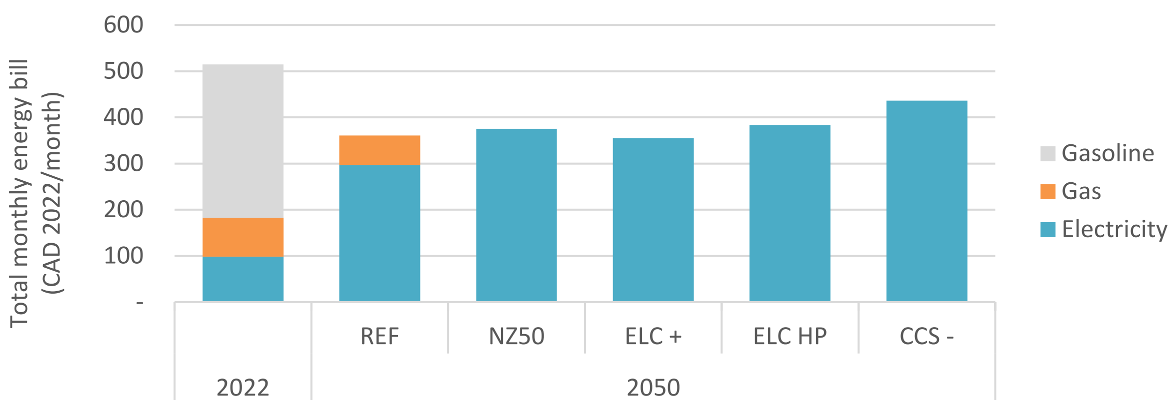


Figure 6-5. Comparison of typical energy bills for a household using the plurality technologies for different integrated pathways for 2050 without OER with legislated carbon price (HST, federal excise tax and provincial fuel tax are included).

However, customers remaining on the natural gas network may experience increasing bills in NZ IPs, as there is a risk that (fixed and volumetric) rates increase significantly as the number of customers on the network decreases as a result of the energy transition. As a consequence, there is risk of stranded assets and the need to abandon gas infrastructure in NZ IPs.

Natural Gas System: Key Considerations

These results broadly lead to the conclusion that under all IPs (REF and NZ IPs), electricity is the most efficient and cheapest energy source - driving households to stay on electricity or switch to it from 2024 to 2050. Gas could become more expensive as the number of consumers decline, negatively impacting energy affordability and potentially leading to a "death spiral" effect (not modelled) for natural gas by 2045-2050 in the NZ IPs. The death spiral refers to a decline in gas consumption and connected customers, leading to higher costs for those remaining and resulting in even higher and faster disconnections.

However, at the same time, as suggested by the least-cost pathway modelling results, it could be of interest for the province to maintain a small but strategic amount of RNG in dual heating systems, especially as Ontario shifts to winter peaking due to space heating electrification. From this perspective, the gas network and consumers who use gas with dual systems may be regarded as an asset for electricity utilities, and alternative compensation that adequately values their service to the electricity system could help to mitigate the death spiral effect.

Alternatively, if death spiral effects make dual systems and continued maintenance of the natural gas system infeasible or too expensive, other solutions, such as on-site thermal storage, could also provide peak shaving services.

6.3 Co-Benefits

Beyond the direct implications of the transition highlighted above, climate change mitigation and the reduction of Ontario's GHG emissions will bring many associated environmental, social and economic co-benefits – including, but not limited to, agricultural productivity, improved human health, economic activity, and reduced risk of disruption of energy systems and conflict.

Based on the social cost of greenhouse gases (SC-GHG), which is a commonly used measure of the societal benefits/damages associated with GHG emissions reductions over a given period of time, achieving GHG emission reductions in-line with the NZ IPs would result in CAD2022 $245B to $874B of cumulative climate change impact mitigation benefits (incremental to the REF IP) from 2019 to 2050, (Figure 6-6). [53]

While investments in the energy sector can also bring co-benefits, such as increasing GDP, creating jobs, and improving Ontario's trade balance, it is also interesting to note that co-benefits

[53] To estimate the benefits associated with the emission reductions modeled in IPs and SAs, Canada's SC-GHG guidelines were used, which include estimates for the social cost of carbon (SCC), the social cost of methane (SCM), and the social cost of nitrous oxide (SCN) discounted through 2080. The federal government provides values for the SC-GHG based on a 2% near-term Ramsey discount rate. Two additional sensitivity scenarios are also provided at 1.5% and 2.5% which are used to calculate the range of cumulative benefits.
Government of Canada, Social Cost of Greenhouse Gas Estimates – Interim Updated Guidance for the Government of Canada. Available online: https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html

due to climate change mitigation are expected to significantly outweigh any incremental investment required to reach net-zero in 2050.

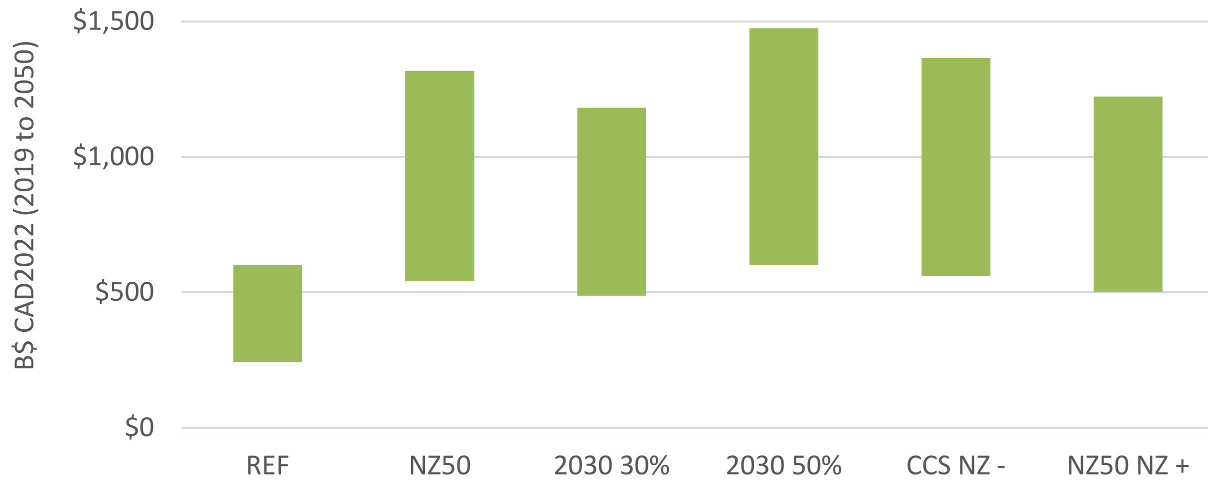


Figure 6-6. Estimated Range of Cumulative Benefits (2019-2050) from Avoided Climate Change Impacts for Key IPs and SAs, compared to a baseline of 2019 annual GHG emissions

While the SC-GHG captures many of the impacts associated with GHGs and climate change, there are some limitations and additional co-benefits should be considered. For example, while some key health impacts are quantified, including heat and cold related mortality and mortality due to extreme weather events and sea level rise, the **SC-GHG does not currently include the health benefits associated with the reduction of other pollutants, such as particulates (e.g., PM2.5).** Quantification of these benefits is challenging due to the uncertain range in potential emission factors, which are technology dependent, as well as the highly localized nature of these impacts, meaning that a proper understanding of the impacts would require regional geographic analysis, which was outside the scope of this study. However, reduction of air pollutants such as PM2.5 and the resulting reduction in human life lost due to poor air quality is another key co-benefit of NZ IPs and SAs.

Further, while the SC-GHG captures many of the impacts related to GHG emissions, it typically does not include other damages associated with increasing concentration of GHGs such as extreme weather events, impacts associated with electricity supply reliability due to extreme weather events, uncertainty around impacts to ecosystem services such as water filtration and wildfire mitigation, national security, and social dynamics including poverty due to high uncertainty in modelling and quantifying these costs. Collectively, these impacts present an unprecedented risk that would have significant impact on our energy needs, economy and prosperity. **Therefore, the full range of estimates of climate change costs / climate change mitigation benefits using SC-GHG should be interpreted as a conservative estimate of the impacts associated with climate change.** Moreover, as the impacts of climate change are difficult to quantify and predict, this study's modelling framework does not consider future climate adaptation requirements for Ontario's energy system.

SECTION 7

7. The Barriers

7.1 Key Barriers to Ontario's Cost-Effective Energy Pathways

This section summarizes key barriers to scaling specific fuels and technologies in Ontario, which may impact the cost-effective pathways' practical implementation. These barriers highlight the complexity of the energy transition in Ontario and the need for targeted action to enable the scaling of fuels and technologies necessary for achieving a net-zero economy.

> This section summarizes key highlights and findings from Deliverable 5: Barrier Identification. For further details, readers can refer to Deliverables 5.

Awareness

There is a general lack of awareness or knowledge among the public and key stakeholders about emerging fuels and technologies still in the early stages of development. These technologies, which have not yet reached commercial operation, do not have the same visibility as more established counterparts. For example, renewable diesel's use cases are largely misunderstood compared to petroleum diesel and biodiesel. This lack of awareness is common across most emerging technologies, including ASHPs, BEVs, electricity storage, and SMRs. Increasing education and awareness is crucial to promote the adoption of these critical technologies.

Public Acceptance

Public hesitation and pushback towards new infrastructure initiatives and the adoption of these fuels and technologies present significant barriers. Concerns about safety and land impacts often lead to resistance against siting SMRs and wind turbines, which are essential for the electricity supply. Similarly, pumped hydro storage projects and the expansion of T&D infrastructure face public opposition. Significant early efforts to engage and communicate with the public are necessary to mitigate these concerns and ensure adequate infrastructure capacity for the short-, mid- and long-term integration of these technologies.

Labour and Supply Chain

There is a significant deficit in skilled workers and supply chain challenges across almost all key fuels and technologies assessed, and addressing this deficit is critical to support their deployment and continued use in the economy. This issue is particularly important for technologies critical to a successful transition, such as ASHPs and BEVs. Expanding T&D infrastructure to support widespread electrification also requires a substantial increase in specialized workforce capacity. Addressing these gaps through targeted training programs and supply chain enhancements is vital for the successful deployment of new technologies.

Investment Uncertainty in New Markets

There is a "chicken and egg" dynamic between the need for robust supply chains and infrastructure to support the introduction of new fuels and technologies and the lack of an existing market to justify investments and their build-out. Key fuels and technologies with high uptake in the long-term, such as hydrogen networks and heavy-duty vehicle (HDV) electrification, may have initial uptake in modelled least-cost pathways in the short- or medium-term and require significant planning, decisions and investments beforehand to generate demand. However, the absence of an established market often deters these investments. For example, the lack of hydrogen storage and transportation infrastructure limits the adoption of hydrogen fuel cell vehicles. Coordinated early and mid-term investments are necessary to stimulate market development and demand.

High Upfront Costs for Long-term Benefits

Many key fuels and technologies for Ontario’s cost-effective energy pathways – including ASHPs and GSHPs, BEVs, and building envelope retrofits – face financial challenges related to high upfront costs for consumers, which create a barrier to adoption even if that fuel or technology may be cost-effective from a societal perspective (and with regards to total cost of ownership) and part of the least-cost pathway to meeting GHG constraints. Policies and programs that offer subsidies for these technologies can help to reduce upfront costs for consumers but remain limited. Additional and longer-term support, particularly for low- and middle-income consumers and small businesses for whom upfront cost represents a significant barrier, will be necessary to encourage adoption and set Ontario on a least-cost pathway to net-zero.

Policy and Regulatory Drivers

A lack of policy and regulatory drivers leaves the uptake of some mature fuels and technologies to voluntary action, stagnating market development. For instance, the absence of regulations enforcing the phase-out of new fossil fuel connections, or the introduction of EV-ready buildings limits the adoption of mature heat pump technologies and retrofit measures. Similarly, the lack of RNG content mandates or carbon intensity requirements for natural gas contributes to slow uptake of RNG and/or hydrogen blending, acting as a barrier to achieving economies of scale for these fuels and the least-cost pathway to net-zero within the province. Implementing clear policies and regulations can improve consumer and investor confidence in decarbonization fuels and technologies and drive the adoption of these fuels and technologies to support Ontario's energy transition.

The Need for Updated Regulations

New and advanced fuels and technologies require updated regulations that promote their use while setting clear guidelines for their integration into the market. For example, storage technologies, crucial for meeting peak demand and capacity constraints, need a regulatory framework that fully recognizes their benefits. Further, CCS and NET technologies are essential for hard-to-abate sectors but lack a supportive regulatory regime in Ontario. The Ontario Mining Act currently prohibits the permanent storage or disposal of any substance, including CO2, on Crown land, significantly limiting sequestration opportunities. Developing clear regulatory guidelines for these technologies is essential to support their market introduction and integration.

Other Considerations and Cross-Jurisdictional Barriers

While the analysis focused on key market, technical, financial, regulatory, social/cultural, and environmental barriers specific to Ontario, there are other barriers that are cross-jurisdictional and influenced by broader factors. These include technology risks, global economic conditions, trade risks, and other considerations that Ontario cannot directly control but which significantly impact the province's energy transition.

Emerging technologies such as hydrogen and SMRs carry inherent risks related to their development and deployment. The uncertainty surrounding the technological readiness, scalability, and cost trajectory of these innovations presents challenges. Early adoption and investment are needed, often before a technology may be profitable, to secure long-term cost declines driving further adoption. Additionally, global supply chain disruptions can affect the availability and cost of critical components, further complicating the integration of new technologies into Ontario’s energy system.

International fuel price fluctuations and global market dynamics also contribute to significant uncertainties. For instance, fluctuations in international fuel prices can influence the cost-effectiveness of different energy sources, affecting investment decisions.

7.2 Implications for Key Technologies and Fuels

The barriers described in the preceding section will have broad implications for scaling the fuels and technologies necessary for Ontario’s clean energy future; however, there are a few key technologies for which these barriers may have an outsized impact on their implementation. This section outlines the implications of the barriers described in the preceding section for select fuels and technologies, including SMRs, biomass, ASHPs, and T&D.

Small Modular Reactors

Since SMRs are still in earlier stages of development, there remains uncertainty surrounding their deployment. Beyond the technical barriers described in Section 4.1, nuclear technologies have faced a longstanding historical opposition and contention, due to societal perception of risks (e.g., related to reactor safety, nuclear waste disposal, proliferation, and security).[54] Therefore, attaining environmental approvals, permitting requirements, and municipal support required for development of these projects will likely be time consuming. Thus, planning, siting, community engagement, and procurement must begin as soon as possible to have projects operational by 2030. Ontario has already begun this process with the Powering Ontario's Growth plan, which announced the deployment of 1,200 MW of SMR capacity at Darlington. The first of these is expected to enter commercial operation in 2029 (assumed to be 2028 in the model).

These considerations also apply to the use of SMR waste heat in DES, which faces similar barriers due to societal perception and public concern regarding nuclear technologies.

Additionally, all the SMR designs under consideration require different forms of fuel that are not currently manufactured in Canada. For example, they may require low-enriched uranium, fuel salts or reprocessing of used fuel from CANDU or other reactors. In some cases, fuels can be procured from an existing global supply. Some forms of fuel have limited global supply, whereas other forms of fuel are still under development.

Wind

Wind energy is a key technology for decarbonizing Ontario's electricity supply and plays a particularly significant role in meeting short-term (2030) needs. Attaining environmental approvals, permitting requirements, and municipal support required for development of these projects is often time consuming thus, planning, siting, community engagement and procurement must begin as soon as possible to have projects operational before 2030.

Additionally, the availability of skilled labor and essential installation equipment, such as hoists and cranes, is limited, potentially slowing down project timelines. For the projected growth in wind capacity to be achievable, there will be a need to increase the supply of skilled workers.

Public resistance to new wind projects, driven by concerns over noise impacts, biodiversity, and the legacy of the Green Energy Act make siting of new projects challenging. Early and transparent communication with communities will be necessary to build support for projects.

Wind is a variable resource, and projects must be sited in areas with adequate wind resources, which may be far from population centers and transmission lines, increasing project costs. Efforts should be made to identify and streamline permitting at suitable locations.

[54] Shobeiri E, Genco F, Hoornweg D, Tokuhiro A. Small Modular Reactor Deployment and Obstacles to Be Overcome. Energies. 2023; 16(8):3468.

Biomass

Bioenergy plays a key role for the decarbonization of sectors and end-uses where electrification is challenging or costly and for use as a negative emission technology. However, there is a limit to the amount of biomass feedstock which can be used sustainably to meet demands. Currently, Ontario is not utilizing biomass feedstocks to its full potential but will need to do so, and optimally, by 2050.

Biomass feedstocks suffer from weak supply chains, including unstable feedstock supply (including cultivation, harvesting, and collection; pre-treatment; and upgrading)[55], lack of qualified workers, and sustainability risks, leading to a perceived high risk and difficulties securing financing for bioenergy projects, programs, and investments at reasonable rates. Given the critical role that biomass plays in achieving net-zero, emphasis should be placed on strengthening and developing supply chains to secure supply. This includes stabilizing feedstock supply, supporting workforce growth, and demonstrating market security to enable better financing options for bioenergy projects.

Biochar

Many of the CCS and NET pathways that become a key factor in achieving net-zero, involve the use of biomass feedstocks. Of these, biochar accounts for the plurality of negative emissions in 2050 in most NZ IPs. In addition to the barriers affecting supply of biomass feedstocks, biochar faces an additional set of barriers that must be addressed to ensure its long-term viability. Biochar used as a soil amendment is a negative emission technology. However, there is a general lack of awareness, among agricultural producers, of the agronomic and environmental benefits of biochar application to cropland.[56] Efforts should be made to educate agricultural producers of these benefits to generate firm market demand.

Additionally, since the transportation of raw biomass is expensive, pyrolysis projects (the dominant pathway for biochar production) are forced to consider feedstocks that are proximate to their site to make production economical. Only recently has there been the development of early mobile pyrolysers which can decentralize pyrolysis and improve the cost-effectiveness of biochar production. To capture economies of scale, the strategic siting of pyrolysis projects to minimize biomass transportation costs should be explored and established early.[57]

Biochar yield, physical properties and carbon content vary depending on pyrolysis conditions, such as temperature, as well as feedstock type, leading to variability in the rate of carbon

55 IRENA. 2022. Bioenergy for the energy transition: Ensuring sustainability and overcoming barriers.
56 Shrestha, R. K. et al. Biochar as a negative emission technology: A synthesis of field research on greenhouse gas emissions. Journal of Environmental Quality, 52, 769–798 (2023).
57 D. Zilberman, D. Laird, C. Rainey, J. Song, G. Kahn. Biochar supply-chain and challenges to commercialization. GCB Bioenergy. 2023;15:7–23.

sequestration.[58] Biochar production pathways should be consistently monitored to ensure they are adequately capturing the benefits and the long-term persistence of the sequestered carbon.

Air Source Heat Pumps

ASHPs become the dominant space heating technology across all IPs in 2050. ASHPs are an established, mature technology; however, a few key barriers exist that stand to limit its adoption. The primary constraint is the lack of a trained workforce for installation and servicing, particularly in the residential sector, including minimal support for training the existing gas equipment technicians and contractors on heat pumps.[59] The pathway for tradespeople looking to specialize in HVAC and heat pumps specifically is complex, sometimes requiring multi-trade trainings, which can be a barrier to attracting new workforce. For the projected uptake of ASHPs to be achievable, there will need to be robust support (e.g., programming, policy, funding) to increase the supply of qualified workers.

While technical and financial barriers are limited, there are some barriers, such as the need for electrical panel upgrades or high upfront costs associated with equipment purchase and installation, which can often be prohibitive. Coupled with the current increased cost of living, building and homeowners see the investment costs of ASHPs as too prohibitive. Addressing these barriers, along with increasing customer awareness, is essential for cost-effective adoption of ASHP installations over fossil fuel systems.

Transmission and Distribution (T&D)

In the NZ IPs, Ontario's economy becomes predominantly electrified and electricity demand also increases significantly in the REF IP. The provincial T&D system is a critical component in supporting new electricity generation projects and enabling the electricity supply to meet system demand at any given time. However, the development of transmission and distribution projects can be a lengthy process. Transmission projects typically take 5-7 years, or longer (7-10 years) for long transmission lines. Distribution projects, while typically faster for small system upgrades (1-3 years), can also take longer for larger projects (e.g., 3-5 years for a new distribution feeder or increase in substation capacity; 7 years or more for a new substation).[60]

The associated challenges and costs can vary significantly based on location (e.g., increased costs due to lack of infrastructure (roads) or the need to build assets that are resilient to changing weather patterns) and future planning. Transmission projects face unique challenges, such as the

[58] Gupta, D.K. *et al.* (2020). Role of Biochar in Carbon Sequestration and Greenhouse Gas Mitigation. In: Singh, J., Singh, C. (eds) Biochar Applications in Agriculture and Environment Management. Springer, Cham. https://doi.org/10.1007/978-3-030-40997-5_7

[59] Posterity Group. 2018. Study of Low Carbon Heating Options for Ontario: Detailed Analysis of Short List Technologies and Fuels.

[60] PG&E, SCE, and SDG&E. (2023). *Joint Presentation on Distribution Planning Process*. Docket Number: 23-IEPR-05, TN#: 250051.

need for Ontario Energy Board leave to construct approval, more extensive and involved environmental approvals, consultation with potentially affected communities, and acquisition of rights of way from landowners. These factors can increase the timeline and cost required to build transmission infrastructure necessary to support the transition. To minimize these barriers, planning and consultation with potentially affected communities should begin immediately.

Beyond the costs of the physical infrastructure, there is a potential significant shortage of skilled labour. In addition, there's a shortage of experienced professionals in key support sectors/fields that are needed to manage all aspects of a transmission line build (e.g., management, environmental professionals, Indigenous engagement). Addressing the need for expanded supply chains and the development of a sufficient, qualified workforce capacity will be paramount to minimizing unnecessary delays due to workforce and supply chain shortages.

According to the modelling done in this study,[61] the relative increase of labour demand in 2050 compared to 2019 in NZ50 is highest for the utilities sector, whose labour force increases 90% from 2019 to 2050.

[61] Modelling of macroeconomic impacts using the North American General Equilibrium Model (NAGEM). See Deliverable 3: Cost-Effective Pathways for more details.

SECTION 8

8. The Solutions

8.1 No-Regret

This section outlines key no-regret solutions to achieving net-zero in Ontario, based on analysis of modelled cost-effective IPs. No-regret solutions are those that are characterized by significant uptake in 8 or 9 NZ IPs (excluding the H2+ IP) and low variability of uptake. **No-regret solutions will be critical to unlocking Ontario's transition to a net-zero economy at least-cost.**

This section summarizes key highlights and findings from Deliverable 6: No- and Least-Regret Solutions. For further details, readers can refer to Deliverables 6.

There are 9 key solutions for 2030 that should be supported immediately

There are nine solutions for 2030 that appear in almost all of the NZ IPs and exhibit little to no variability in the magnitude of uptake (i.e., no-regret solutions), described in Table 8-1. Early success across these nine solutions will be critical to long-term decarbonization.

No-regret solutions for 2030 are concentrated in the buildings, transportation, and energy supply sectors, indicating that these sectors are critical areas for early action. In contrast, solutions for sectors including agriculture, industry, and carbon capture and negative emissions technologies are less certain in the short-term.

Table 8-1. No-Regret Solutions for 2030

#	Solution
	Buildings
1	Pursue full economic potential for demand reduction in the building sector through energy efficiency and building control measures.
2	Pursue rapid electrification of residential and commercial space heating with ASHPs.
	Transportation
7	Pursue the rapid electrification of light- and medium-duty vehicles via batteries as well as the majority of buses.
	Energy Supply – Electricity
27	Continue to deploy electricity storage technologies to meet near-term (before 2030) capacity requirements and peak demand.
28	Deploy onshore wind as a solution to meeting near-term 2030 system needs and monitor the need for additional growth by 2050.
29	Build out electricity T&D infrastructure within Ontario.

#	Solution
30	Deploy rooftop PV and other distributed energy resources (DERs) to meet system needs.
32	Continue exploration and **development of SMRs** to reduce first-of-kind deployment risks and work with federal government to ensure that its regulatory processes facilitate timely and safe deployment, to achieve economies of scale and enable significant growth in SMR capacity by 2050, per the Powering Ontario's Growth initiative.
	Energy Supply – Clean Fuels
34	Ramp up the sustainable utilization of forests to fulfill the growing demand for biomass.

The electricity sector offers several immediate, no-regret solutions. There are five short-term, no-regret solutions for electricity, indicating that the sector is a key action area for early progress toward net-zero. These near-term solutions comprise electricity storage, onshore wind, T&D, solar PV and DERs, and SMRs.

For **transportation,** electrifying light- and medium-duty on-road vehicles using batteries is a no-regret solution for 2030, as BEV technologies are already nearing cost-parity on a total cost of ownership basis with their fossil fuel counterparts on a total cost of ownership basis. Across all NZ IPs, the entire light-duty vehicle segment and medium-duty freight trucks are electrified. In the longer-term, partial electrification is expected to play a role in reducing GHG emissions from off-road transportation.

In **buildings**, the path to decarbonization is clear: five out of six solutions identified in the building sector are no-regret. Solutions for 2030 and 2050 in the buildings sector have high certainty, so much so that there is similar uptake of technologies across NZ IPs and the reference case for most technologies. GHG emissions reductions are driven by the electrification of space and water heating in both residential and commercial sectors, and these technologies are mature and receive policy support, facing limited uncertainty. ASHPs become the dominant space heating technology across all IPs (including the REF IP), supplying 59-60% and 32-54% of annual useful heating demand in residential and commercial sectors respectively in 2050.

Progress on building envelope retrofits and control measures by 2030 is foundational for success in the sector, as many of the 2050 solutions build on their implementation. The no-regret solutions for 2030 can be pursued with a high degree of confidence as early as possible (before 2030) by providing continued policy support and addressing any remaining market or financial barriers.

No-regret **clean fuels** solutions focus on maximizing the sustainable use of biomass resources to meet growing energy demands. For 2030, this involves ramping up the utilization of forest residues, ensuring that this abundant and renewable resource is effectively harnessed. By 2050, the strategy expands to include the maximum sustainable utilization of various biomass feedstocks such as agricultural residues, source-separated organics, and dedicated fast-growing trees and crops, diversifying the biomass supply.

By 2050, there are several additional no-regret solutions, in industry and agriculture, and negative emissions technologies

Both solutions identified for the **agriculture** sector are classified as no-regret for 2050. Decarbonization in this sector is dependent on two key fuels: electricity and RNG. There is some uncertainty to the extent and pace with which early electrification occurs. Regardless, sufficient T&D capacity to meet the increased load in more rural areas where agricultural producers are typically located (not modelled) will be necessary. RNG plays an important role in the long-term, representing approximately 19% of agricultural final energy consumption in 2050.

In **industry**, strategic use of RNG is expected to be a key solution for select hard-to-electrify end-uses, especially those requiring high-grade heat. Alongside this, pursuing all cost-effective electrification opportunities within the industrial sector, particularly in manufacturing, will play a crucial role in reducing GHG emissions and enhancing energy efficiency. Across all NZ IPs, electricity accounts for a minimum of 42% of annual energy demand in 2050, 63% of which is consumed within the manufacturing industry.

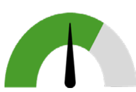
For **carbon capture and negative emissions technologies**, no-regret solutions include biochar production and leveraging carbon capture technologies to capture CO2 from industrial processes and energy production. These solutions provide the necessary tools to offset GHG emissions from hard-to-abate sectors.

A full list of no-regret solutions for 2050 (excluding no-regret solutions for 2030) across sectors is presented in Table 8-2.

Table 8-2. No-Regret Solutions for 2050 (excluding no-regret solutions for 2030)

	Solution
	Buildings
3	Pursue the decarbonization of residential and commercial space heating with DES.
4	Pursue the use of GSHPs to meet space heating demand in commercial buildings.
5	Leverage waste heat to meet space heating demand in residential and commercial buildings.
	Transportation
10	Pursue the partial electrification of off-road transportation, mainly agricultural machinery.

	Solution
	Industry
15	Pursue the strategic use of RNG in select hard-to-electrify end-uses, mainly processes requiring high-grade heat.
16	Pursue significant electrification of the industrial sector, particularly within the manufacturing industry
	Agriculture
18	Pursue widespread electrification of the agricultural sector.
19	Pursue the strategic use of RNG to decarbonize the remaining hard to electrify end-uses.
	Carbon Capture and Negative Emissions Technologies
20	Pursue biochar production as the primary pathway for negative emissions.
21	Leverage carbon capture technologies to capture CO2 from industry and energy production.
	Energy Supply – Electricity
31	Deploy 7 GW of advanced (GEN III+) and conventional nuclear reactors. Note: This solution is driven by the Powering Ontario's Growth initiative and is already underway.
	Energy Supply – Clean Fuels
35	Pursue the maximum sustainable utilization of most available biomass feedstocks (beyond forest residues and roundwood) in particular, agricultural residues, source separated organics, and dedicated fast-growing trees and crops.



8.2 Least-Regret

Least-regret solutions are solutions that have significant uptake in 8 or 9 NZ IPs (excluding the H2+ IP) but have high variability in the magnitude of their contribution. **Least-regret solutions will also be critical to unlocking Ontario's transition to a net-zero economy at least-cost**, although the magnitude of their contribution is uncertain. Immediate support for least-regret solutions may also be required if Ontario wishes to pursue modelled least-cost net zero pathways.

Least-regret solutions for 2050 (excluding those that are no-regret solutions for 2030) are summarized in Table 8-3.

Table 8-3. Least-regret solutions for 2050 (excluding no-regret solutions for 2030)

	Solution
	Buildings

	Solution
6	Actively explore, invest in, and pilot the use of commercial dual-fuel heating systems, in addition to all-electric ASHPs.
	Transportation
8	Pursue the electrification of rail transportation.[62]
11	Actively explore, invest in and pilot industrial off-road decarbonization that can be achieved with bioenergy.
14	Actively explore, invest in and pilot the use of catenary vehicles (CAT) to decarbonize the heavy-duty vehicle segment.
	Industry
17	Actively explore, invest in, and pilot hydrogen as a replacement for natural gas.
	Carbon Capture and Negative Emissions Technologies
24	Actively explore, invest in, and pilot opportunities to use Bioenergy with Carbon Capture and Storage (BECCS) as supplemental negative emissions technologies to biochar.
25	Introduce DAC as a negative emissions technology to sequester any remaining emissions in 2050.
	Energy Supply – Clean Fuels
36	Determine the degree to which hydrogen produced from BECCS can contribute to overall energy consumption.
38	Develop a robust hydrogen pipeline network to facilitate transportation of centralized hydrogen production.

8.3 Wild cards

Wild card solutions are those with significant uptake in 1 to 7 NZ IPs (excluding the H2+ IP). The lower consistency across NZ IPs could point to higher uncertainty regarding their cost-effectiveness relative to other solutions. Immediate support for wild card solutions may also be required if Ontario wishes to pursue modelled least-cost net zero pathways. Wild card solutions are observed in the transportation sector, carbon capture and negative emissions technologies, electricity, and clean fuels, with key uncertainties relating to hydrogen and carbon sequestration. Notably, there are no wild card solutions in the buildings sector, as solutions for the buildings sector are more certain.

[62] Note that the rail transportation sector in the model excludes light-rapid transit and subways, which are categorized under road transport.

These wild card solutions are less certain but could offer transformative solutions depending on technological advancements and market conditions. Their successful implementation hinges on careful observation, timely decision-making, and strategic investments to overcome existing uncertainties.

Regarding **carbon sequestration,** there is a high degree of certainty that Ontario will need to capture a significant amount of CO2 (whether with DAC, BECCS, or other CCS). However, there is less certainty as to where the captured CO2 will be allocated (exports, domestic sequestration, or utilization). Accordingly, CCS solutions related to domestic sequestration and exports are classified as wild cards.

The biggest uncertainty in the **transportation** sector is the least-cost pathway for decarbonization of HDVs. While catenary vehicles are a least-regret solution for 2050, even by 2050, HDV solutions of FCEVs and BEVs are wild cards and will depend heavily on the evolution of the future hydrogen and electricity landscape. However, specialized infrastructure is required for all zero-emission HDV technologies, and therefore success for HDV transition is dependent on careful observation of electricity and hydrogen conditions and timely decision making/investments. Wild card solutions for 2050 are summarized in Table 8-4.

Table 8-4. Wild card solutions for 2050

	Solution
	Transportation
9	Actively explore, invest in, and pilot using hydrogen and biofuels to complement electricity in decarbonizing rail transportation.[63]
12	Determine the role of FCEV in decarbonizing the heavy-duty vehicle segment; and initiate pilots.
13	Actively explore, invest in, and pilot the use of battery-electric vehicles (BEV) to decarbonize the heavy-duty vehicle segment.
	Carbon Capture and Negative Emissions Technologies
22	Identify and develop sites and infrastructure needed to geologically sequester captured carbon within Ontario.
23	Actively explore, invest in, and pilot exporting captured CO2 to the United States (US) for sequestration or utilization.
26	Actively explore opportunities for capturing and utilizing CO2 emissions from industry and energy production.
	Energy Supply – Electricity

[63] Note that the rail transportation sector in the model excludes light-rapid transit and subways, which are categorized under road transport.

	Solution
33	Examine the role of hydrogen turbines in meeting peak electricity demand
	Energy Supply – Clean Fuels
37	Actively monitor technological advancements and market conditions for other clean hydrogen production pathways: blue and electrolytic hydrogen; and invest in, and initiate pilots.

SECTION 9

9. Conclusion

9.1 Key Takeaways

This study explores several pathways to decarbonizing Ontario's energy system in 2050 in a least-cost manner. The results highlight several critical key takeaways that provide insights into Ontario's energy transition and the pathway to a net-zero economy.

èTakeaway 1: The transition's positive outcomes on energy affordability and societal co-benefits will offset energy investment costs and GDP impacts

The net-zero transition will have numerous implications. **At a macro-economic scale, there will be minor aggregate impacts to GDP and labour demand.** GDP growth is expected to be negligibly lower in the NZ IPs compared to REF, but economic growth continues, and the impact is minor (0.04 percentage points per year[64] lower in NZ50); the energy sector represents only a small piece of Ontario's overall economy.

At a more granular level, consumer energy bills will also be impacted by the transition. **Average ("normalized") household energy bills are expected to decline substantially in both the REF and NZ IPs, e.g. 47% from 2022 to 2050 in NZ50,** [65] as fuel switching, and other energy savings lead to lower overall energy consumption. However, there is risk of increasing energy bills for households remaining on natural gas as consumer numbers drop in net-zero pathways.

Besides this, the net-zero transition is expected to have **numerous co-benefits, such as improved human health, avoided impacts on agricultural productivity and economic activity, and reduced risk of disruption to energy systems.** While quantifying these benefits is challenging, the social cost of greenhouse gases (SC-GHG) can be an effective metric for assessing potential benefits/avoided damages. Based on Canada's federal SC-GHG values, cumulative benefits resulting from **avoided damages associated with CO2, CH4 and N20 emissions reductions are estimated to range from 245 to 874 B$ CAD2022 cumulatively (2019-2050) across the NZ IPs (incremental to the REF IP).** While investments in the energy sector can also bring co-benefits, such as GDP growth, job creation, and decreasing Ontario's trade deficit, it is also interesting to note that **co-benefits due to climate change mitigation are expected to significantly outweigh any incremental investment required to reach the net-zero in 2050.**

[64] Difference in average real annual growth (%/y) (2019-2050) between REF and NZ50.
[65] Without OER and with the legislated carbon price

è Takeaway 2: Significant action and investments are required to reach net-zero

Achieving net-zero in 2050 will require significant action and financial investment. In the least-cost REF pathway, Ontario would reach its 2030 GHG emissions target if all assumed policies and actions materialize. However, business-as-usual policies, including committed policies, fall short of net-zero in 2050.

Putting Ontario's economy on a pathway to achieve net-zero in 2050 will require additional investments on the order of 173 B$ CAD2022 in the NZ50 IP (cumulative from 2019 to 2050) beyond what would occur in the REF IP. A majority of this incremental investment goes towards electricity generation capacity and T&D infrastructure to expand the electricity system to meet the expected doubling or tripling of demand from 2019 to 2050 in the NZ IPs. The necessary developments across many sectors will require coordinated commitments from federal, provincial, and municipal governments, Indigenous communities, along with other stakeholders, to support the energy transition.

èTakeaway 3: A major energy system transition is required to reach net-zero

In all NZ IPs, significant changes in Ontario's energy supply, demand, and infrastructure are needed to meet net-zero in 2050. Despite the nuances across the results from the NZ IPs and SAs modeled in the study, four key pillars are required to enable a least-cost pathway for Ontario to achieve net-zero in 2050.

1. **REDUCING** total final energy consumption relative to current forecasts through a significant acceleration of the pace and magnitude of energy efficiency efforts (with uptake of all cost-effective energy efficiency potential), and leveraging the efficiency gains associated with fuel-switching in key end-uses and applications across the economy;
2. **SWITCHING** greater than 80% of fossil fuel use, including the vast majority of heating, mobility and industrial needs, to predominantly emission-free electricity, with targeted use of clean fuels such as biofuels, clean hydrogen and RNG to support decarbonization in harder-to-electrify subsectors from 2019 to 2050;
3. **GROWING** electricity generation capacity, e.g. to over 2x in NZ50, primarily through new additions of wind, nuclear (mainly SMRs), energy storage (batteries and pumped hydro), and solar, and growing the associated transmission and distribution capacity from 2019 to 2050;
4. **SEQUESTERING** remaining GHG emissions (~20% of 2019) using CCS and negative emissions technologies, e.g., biochar, DAC, and BECCS.

èTakeaway 4: Several uncertainties and nuances will determine the exact trajectories

Despite the directional alignment of these four pillars across the modeled integrated pathways, the results also highlight specific nuanced considerations and uncertainties around:

- **The role of clean fuels**. Biofuels, RNG, clean hydrogen and synthetic fuels play a key strategic role in decarbonizing specific segments and end-uses where electrification is challenging and/or costly. However, their role may vary, depending on their market conditions and how favourable conditions are for electrification.
- **The magnitude of electricity growth.** The NZ IPs and SAs clearly indicate that significant growth of electricity generating capacity is key to achieving net-zero. However, the range of this growth varies – capacity grows to 2.0 to 3.2x between 2019-2050.
- **The trade-offs between wind and nuclear.** Both wind and nuclear (SMRs) are key to the future generation mix as complementary technologies. However, the relative contributions of wind vs. SMRs to the overall mix is sensitive to assumptions regarding the evolution of technology costs for SMRs in particular. In earlier years, the results consistently show wind capacity additions, but post-2040, there is less certainty.
- **The potential of CCS and negative emissions.** All NZ IPs and SAs use the maximum amount of geologic sequestration and a significant amount of biochar in 2050. However, there is some uncertainty regarding the capacity for long-term geologic sequestration of CO2, and annual budget for CO2 geologic storage, assuming Ontario may require these solutions to maintain net-zero or achieve negative emissions post-2050.
- **Future government policies, innovations, and climate impacts are key uncertainties.** These uncertainties (beyond emerging technologies and projected climate impacts on temperature) are not modelled because they are out of scope, or their development is largely unknown. However, it is expected that these factors and technology improvements beyond what is modeled will be major determinants of a transition to net-zero. New policies will be required to achieve the GHG emissions reductions imposed in the modelling work, represented by the evolving long-term marginal cost of carbon.

èTakeaway 5: There are 9 key solutions for 2030 that should be supported immediately

There are nine solutions for 2030 that appear in almost all of the NZ IPs and exhibit little to no variability in the magnitude of uptake (i.e., no-regret solutions). Early success across these nine solutions will be critical to long-term decarbonization. The nine solutions are:

- Pursue full economic potential for demand reduction in the building sector through **energy efficiency and building control measures**,
- Pursue the rapid **electrification of residential and commercial space heating** with ASHPs,
- Pursue the rapid **electrification via batteries of light-and medium duty vehicles as well as buses**,
- Continue to deploy **electricity storage technologies** to meet near-term (before 2030) capacity requirements and peak demand,
- Deploy **onshore wind** as a solution to meeting near-term 2030 system needs and monitor the need for additional growth by 2050,
- Build out **electricity T&D infrastructure** within Ontario,
- Deploy rooftop PV and other **distributed energy resources (DERs)** to meet system needs,
- Continue exploration and **development of SMRs** to reduce first-of-kind deployment risks and work with federal government to ensure that its regulatory processes facilitate timely and safe deployment, to achieve economies of scale and enable significant growth in SMR capacity by 2050,
- Ramp up the **sustainable utilization of forests** to fulfill the growing demand for biomass.

While least-regret and wild card solutions exhibit less consistency and/or more variability across the IPs, this does not indicate that no action is required. Immediate support from select stakeholders may be necessary if Ontario wishes to pursue modelled least-cost net-zero pathways.

èTakeaway 6: Advanced planning and decisions between now and 2030 will have important implications for the success and cost-effectiveness of solutions for 2050

Many solutions for 2050 require significant infrastructure development to support their implementation – for example, the construction of heavy-duty vehicle charging or hydrogen refuelling stations and expanded T&D to support industrial and agricultural electrification. Bioenergy plays a key role in decarbonization in sectors where electrification is challenging and costly – however, there is a limit to the amount of biomass feedstock which can be used sustainably to meet competing demands. Immediate efforts should be made to ramp-up supply of sustainable biomass feedstocks – and in tandem, a detailed roadmap for strategic and cost-effective allocation of this limited resource must be developed. Further, early exploration and developments in some technologies – such as the work being conducted for SMRs – will be key to ensuring that learnings can enable achievement of future cost reductions associated with Ontario-specific barriers. In the absence of timely decision-making, the cost of implementing solutions for 2050 may become higher, and the risk of not meeting net-zero in 2050 can increase.

For solutions for 2050, analysis beyond the scope of this deliverable is needed to determine the required timing of decisions, planning, construction, development of a supply chain, etc. Almost all solutions for 2050 have initial uptake in the modelled IPs before 2050 and require action before 2030, including developing regulatory frameworks, encouraging technology adoption and early investment, beginning infrastructure development, developing stable supply chains, and re-training of skilled workers. For example, in most NZ IPs, while CCS doesn't have "significant" uptake in 2030, some uptake starts as early as 2027. For other solutions for 2050, the evolution of market, policy, and technology conditions will need to be closely monitored in the meantime.

ANNEX A

Appendices

Appendix A: Model Descriptions

North American Times Energy Model (NATEM)

NATEM is the only economy-wide integrated energy system optimization model in Canada. NATEM-Canada describes the entire integrated energy system, as well as non-energy emitting sectors of the 13 Canadian jurisdictions, and provides a rigorous analytical basis for identifying least-cost solutions to achieve energy and climate objectives without compromising economic growth. NATEM includes thousands of technologies allowing modelled results to reach deep decarbonization levels (including net-zero targets by 2050).

NATEM follows a techno-economic modelling approach to describe the energy systems of North American jurisdictions through a large variety of specific energy technologies characterized with their technical and economic attributes as well as GHG emission factors. It offers a detailed representation of an energy sector, which includes extraction, transformation, distribution, end uses, and trade of various energy forms and materials.

NATEM distinguishes between generation technologies that convert primary energy into secondary energy (e.g., refineries, power plants, etc.) and end-use devices that transform final energy into energy services (e.g., cars that serve a demand for mobility, light bulbs that serve a demand for lighting). In particular, they include existing technologies, improved versions of the same technologies and emerging technologies, all characterized by their technical and economic attributes. Consequently, it allows for detailed accounting of all energy flows within the energy sector from primary energy extraction to final energy consumption. NATEM will select technologies based on what is optimal across all sectors of the energy system since they will be competing for the same resources. For instance, biomass feedstock is a limited resource, and the model will decide what are the best uses for this resource (e.g., biofuel production) and which end-use sectors will consume this fuel.

Sector service demand is an exogenous input to the model which is independent of fuel types or technologies. For example, demand for transportation will be in passenger-km per year and demand for heating or cooling will be in m2 of buildings. Furthermore, only prices for import/export external to the model system boundary (e.g., Canada) will be set exogenously, while all other commodity prices will be determined endogenously by the model. NATEM will determine the solution that both minimizes net discounted costs and maximizes economic surplus, e.g., NATEM integrates demand price elasticity and computes partial equilibrium. In all cases, the model solution must meet a set of constraints: supply must at least equal demand, emissions targets much be met, and other policies must be respected.

North American General Equilibrium Model (NAGEM)

NAGEM is a new generation dynamic macroeconomic model able to simulate deep transformation of the economy to achieve ambitious objectives of GHG reduction. This is the first model in Canada applied to identify economy transformation pathways for net-zero scenarios. It can be used as a standalone model or with NATEM, which is done in this study through a soft-linking between the two models.

NAGEM is composed of detailed economic models of the 13 Canadian jurisdictions, including inter-jurisdictional flows of trade and labour. The model starts from the baseline year reflecting the structure of the Canadian economy being in equilibrium. The model accounts for the inter-dependencies between different sectors, economic agents (industries, households, provincial and federal governments) and markets in the economy. Energy and climate policies are modelled and NAGEM derives the optimal economic solution by converging to a new set of prices, allocation of goods, capital, and labour to allow economic equilibrium.

RateVision

RateVision is used to evaluate the impact on tariffs[66] for distribution connected gas and electricity consumers in residential, commercial, and industrial categories. The model relies on the outputs from NATEM regarding future gas and electricity consumption, capacity expansion, and capital and operational costs, as well as current tariffs design specifics and regulation. The model outputs include annual revenues requirements for different cost categories for utilities, variable rates including commodity (gas or electricity) price, transportation/transmission, and distribution variable rates and fixed charges. For the natural gas distribution system, the RateVision estimates the level of abandonment under a decreasing number of connected consumers, reduction of revenues requirement, decommissioning and stranded assets cost for each time period until 2050 (typically 5-year steps). The model evaluates how stranded assets costs impact distribution volumetric rates and fixed charges. RateVision is not able to simulate the death spiral effect (natural gas consumers switching to electricity under increasing rates, pushing rates even higher), but it provides insights on the increase in fixed charges and variable rates that may initiate this effect.

RateVision estimates the normalized energy cost per provincial household and calculates energy bills for different household archetypes; their possible energy technology switch and changing energy demand under the effect of climate change.

For more information about NATEM, NAGEM, or RateVision, contact ESMIA at info@esmia.ca

[66] The term "tariffs" refers to both fixed charges and variable rates.

Appendix B. Sensitivity Analyses

Table B-1. Description of Sensitivity Analyses Conducted for Key Integrated Pathways.

IP	SA Label	Description
NZ50	**NZ50 SMR+**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Lower cost of SMR (-45% in 2050).
NZ50	**NZ50 SMR-**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Higher cost of SMR (+45% in 2050).
NZ50	**NZ50 NZ+**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. The exogenous GHG constraints are set assuming exogenous uptake of natural solutions, allowing for 3.57 and 10.59 Mt CO2eq/y more GHGs in 2030 and 2050 respectively. Natural solutions would otherwise be assumed to have no impact on the energy sector (e.g., they are assumed to have no cost, require no energy, and do not impact biomass supply).
NZ50	**NZ50 HURD**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Hurdle rates increased by sector. The minimum hurdle rates by sector are as follows: Agriculture: 18%, Commercial: 12%, Residential: 8%, Transportation: 21%, Industrial: 18%.
NZ50	**NZ50 ELC**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Electricity adequacy: lower wind and solar guaranteed contribution to peak. For wind, the values in the first level of the supply curve in Winter is 10%, Summer is 4%. Solar values are zero. Constraint on minimum storage required for renewables has been removed.
NZ50	**NZ50 LIM ELC**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Lower growth in additional capacity.

IP	SA Label	Description
NZ50	**NZ50 LIM ALL**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Build limit on several technologies: electricity (same as from the NZ50-LIM-ELC SA), hydrogen, biofuel production, transportation (medium & heavy duty, buses, rail), residential space heating, commercial space heating, and industrial boilers.
CCS-	**CCS NZ-**	GHG reduction of 40% in 2030 from 2005 levels and net-zero in 2050, in addition to "business-as-usual" including committed policies. Unfavourable CCS and NET conditions. GHG total includes international marine and aviation.

This is **Exhibit D** referred to in the affidavit of Susan Brandum sworn or affirmed before me on July 25, 2025.

____

Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C


¡NOW!
END FOSSIL FUEL
¡NOW!
END FOSSIL FUEL
END FOSSIL FUEL
¡NOW!
END FOSSIL FUEL
¡NOW!


GAS IS PAST! HEAT PUMPS are the FUTURE
END FOSSIL FUELS
HELP!
WE'RE ON FIRE!
CELEBRATE
END FOSSIL FUEL
WAKE UP
Time


GAS
IS
PAST!
HEAT PUMPS
are the
CLIMATE
CHANGE
OUR
GRANDCHILDREN
PAY THE PRICE


DON'T BE FOSSIL FOOLED
END FOSSIL FUELS


END FOSSIL FUEL !Now!
END FOSSIL FUEL !Now!
END FOSSIL FUEL !Now!
END FOSSIL FUEL !Now!
GAS
heats the
EARTH
HEAT PUMPS
COOL


WE LOVE
HEAT PUMPS !!!
END FOSSIL FUEL
END FOSSIL FUELS
GAS IS PAST!
HEAT PUMPS are the FUTURE


NO NEW FOSSIL NATURAL GAS
A GOOD PLANET IS HARD TO FIND
WE ONLY HAVE ONE
HEAT PUMPS $AVE


GAS IS PAST!
HEAT PUMPS are the FUTURE
HELP!
WE'RE ON FIRE!


NO
FOSSIL
EXPANS
WE LOVE
HEAT
PUMPS
!!!


OIL FREE
LIVE FREE


WE LOVE
HEAT PUMPS
!!!
CAP
OIL & GAS
EMISSIONS
NOW!


CELEBRATE
EARTH
Less Stuff

This is **Exhibit E** referred to in the affidavit of Susan Brandum sworn or affirmed before me on July 25, 2025.

____

Commissioner for Taking Affidavits
Kate Siemiatycki
LSO No. 72392C

environmental defence
INSPIRING CHANGE

June 19, 2023

Josephine Palumbo
Deputy Commissioner, Deceptive Marketing Practices
Competition Bureau
Place du Portage I
50 Victoria Street, Room C-114
Gatineau, Quebec K1A 0C9
Josephine.Palumbo@canada.ca

Dear Ms. Palumbo,

Re: Enbridge Gas Deceptive Marketing Practices

We are writing to request that the Commissioner of Competition commence an inquiry into deceptive marketing practices by Enbridge Gas Inc. ("Enbridge") under s. 9 of the *Competition Act*. As detailed below, Enbridge is misleading consumers into connecting to its gas system using false and misleading representations contrary to sections 52 and 74.01 of the *Competition Act*. Enbridge is telling potential customers that gas is the most cost-effective way to heat their homes and suggesting that it is "clean energy" and "low carbon." None of these representations are true.

These representations are causing real harm. Customers in gas expansion areas stand to lose approximately $20,000 on average if they switch to gas instead of installing a high-efficiency electric heat pump (over the lifetime of the equipment).[1] This will also create far more carbon pollution, making it more difficult and expensive to reach federal climate targets.

We also request temporary orders to stop Enbridge from deceiving potential customers while the proceeding progresses. Enbridge is making these false and misleading representations on an ongoing basis. With each week that passes, more customers sign up to convert their heating to gas instead of purchasing a high-efficiency electric heat pump resulting in unnecessarily high energy costs and carbon pollution to the detriment of consumers, competition, and the climate.

[1] Dr. Heather McDiarmid, *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps*, August 2, 2022, p. 11 (link); For the difference in costs with the latest gas prices, see Ontario Clean Air Alliance, *Heat Pump Calculator for New Gas Communities* (link); see also Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, p. 23 (link). The actual savings depend on a variety of factors. See pages 5 and 6 for examples.

Background

Enbridge Inc. and Methane Gas

Enbridge owns nearly all of the methane gas distribution pipelines in Ontario. Methane gas is commonly known as "natural gas". However, methane gas is a potent greenhouse gas that pollutes the environment and causes climate change when it is burned and when it leaks from hydraulic fracturing extraction sites, pipelines, storage facilities, and customer equipment. The combustion of methane gas alone is responsible for approximately one-third of Ontario's greenhouse gas emissions.[2] Heating homes and businesses with gas accounts for approximately 19% of Ontario's green house gas emissions.[3]

In Ontario, Enbridge earns profit by investing in gas pipelines. It therefore has a strong financial interest in encouraging Ontario homes and businesses to switch to gas and remain with gas. The more capital that needs to be invested in pipelines, the more Enbridge stands to earn in profit. Enbridge also has a strong financial interest in gaining and keeping customers to pay for the pipelines it has already built through gas distribution charges that are levied on all customers on their gas bills.

Enbridge has no real competition when it comes to the distribution of gas in Ontario.[4] Due to a past market consolidation, Enbridge serves over 99.7% of all gas customers in the province.[5]

Enbridge's main competitors in Ontario are in fact electricity distribution companies. Most of these electricity distribution companies are owned by municipalities, like Toronto Hydro or Hydro Ottawa. The biggest threat to Enbridge's business is that its customers convert from gas heating to high-efficiency electric cold climate heat pumps. Another threat is that customers with expensive oil heating decide to switch to electric heat pumps instead of gas.

Enbridge has an additional interest in gaining and keeping gas customers in Ontario because it and its parent and sister companies own many of the large gas transmission pipes that bring gas to Ontario and move it between regions within

---

[2] Enbridge Evidence in Ontario Energy Board File #EB-2022-0200, Exhibit 1, Tab 10, Schedule 3, Page 2 (link).
[3] Dr. Heather McDiarmid, *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps*, August 2, 2022, p. 8 (link).
[4] Gas distribution pipelines are a natural monopoly. Each gas distribution company has a monopoly in the area it serves.
[5] Ontario Energy Board, Yearbook of Natural Gas Distributors, 2021/22, p. 15 (link).

Ontario. If gas demand stops growing or falls, Enbridge and its parent and sister companies could lose revenue.

The Context: Gas Expansion Communities

The deceptive marketing in this case was (and continues to be) directed to customers in gas expansion communities. These are small existing communities that Enbridge is adding to its gas system through a government program.[6] Like everywhere else in its system, Enbridge has an interest in signing up new customers in these communities, to help to trigger "upstream" capital investments that Enbridge profits from. New customers also help to generate the revenue needed to pay for existing infrastructure.

Enbridge has a particularly strong interest in signing up new customers in these gas expansion communities because it is required to maintain a "ten-year rate stability period" for each project.[7] That means that Enbridge bears the financial risk for that ten-year period that too few customers connect to the new pipeline to pay for it.[8]

The Competition: High-Efficiency Cold Climate Heat Pumps

For a long time, methane gas was the cheapest way to heat homes. However, electric cold climate heat pumps are now much cheaper than gas for consumers.[9] Annual costs are lower because heat pumps are approximately three times more efficient than gas furnaces (or five times for ground-source heat pumps, also known as geothermal) and because customers can avoid paying monthly charges to Enbridge for use of its gas system.[10] Upfront equipment costs are also often lower because heat pumps provide both heating and cooling in one unit and because of federal rebates.

Heat pumps are so efficient because they *move* heat instead of *converting* gas or electricity into heat. Standard gas and electric heating cannot surpass 100% efficiency, whereas heat pumps can be multiple times more efficient – they can use 1 kW of electricity to move 3 kW of heat (or more) indoors. They can do this even

---

[6] For background on the program, see: Globe and Mail, *Ontario increasing reliance on natural gas as others move away from fossil fuels*, June 11, 2021 (link).
[7] Ontario Energy Board, Letter Re Potential Projects to Expand Access to Natural Gas Distribution, March 5, 2020. p. 7-8 (link).
[8] *Ibid*.
[9] Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, p. 23 (link); Dr. Heather McDiarmid, *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps*, August 2, 2022, p. 11 (link); For the difference in costs with the latest gas prices, see Ontario Clean Air Alliance, *Heat Pump Calculator for New Gas Communities*, (link).
[10] National Resources Canada, *Heating and Cooling With a Heat Pump*, (link).

in cold temperatures because, counterintuitively, there is still a great deal of heat energy in very cold air.[11]

Customers are very vulnerable to deceptive advertising about the benefits of gas heating because most are not aware of heat pumps or the advancements that have been made in heat pumps in recent years. Recent changes that have made heat pumps less expensive than gas heating include the following:

- The efficiency of heat pumps has been increasing with advancements such as variable speed compressors.[12] Units available in Canada are up to 380% efficient even in cold areas like Ottawa (and more for ground source heat pumps).[13] More efficient units are cheaper to operate because they use less electricity.

- Heat pumps are now able to provide heating in Ontario's cold winters.[14]

- Canada's steadily increasing price on carbon pollution makes gas heating more and more expensive every year vis-à-vis electrical heating. By 2030, the carbon pollution price on gas will equal 32.40 cents/m^3.[15] By comparison, that amounts to over *three times* the price charged by Enbridge for methane gas in Toronto in January of 2020 (10.19 cents/m^3).[16]

---

[11] National Resources Canada, *Heating and Cooling With a Heat Pump*, (link) ("It may be surprising to know that even when outdoor temperatures are cold, a good deal of energy is still available that can be extracted and delivered to the building. For example, the heat content of air at -18°C equates to 85% of the heat contained at 21°C. This allows the heat pump to provide a good deal of heating, even during colder weather.")
[12] Enbridge Gas, Federal Carbon Charge (link).
[13] National Resources Canada, Heating and Cooling With a Heat Pump (link). National Resources Canada notes: "On a seasonal basis, the heating seasonal performance factor (HSPF) of market available units can vary from 7.1 to 13.2 (Region V). It is important to note that these HSPF estimates are for an area with a climate similar to Ottawa. Actual savings are highly dependant on the location of your heat pump installation." Most Ontarians live south of Ottawa. The conversion factor between HSPF and a seasonal Co-Efficient of Performance (sCOP) is HSPF*0.293. An HSPF of 13.2 amounts to an sCOP of 3.8676, which equates to the heat energy output from the unit being 386% of the electrical energy input into the unit.
[14] National Resources Canada, *Heating and Cooling With a Heat Pump*, (link) ("More recently, air-source heat pumps that are better adapted to operating in the cold Canadian climate have been introduced to the market. These systems, often called cold climate heat pumps, combine variable capacity compressors with improved heat exchanger designs and controls to maximize heating capacity at colder air temperatures, while maintaining high efficiencies during milder conditions.").
[15] Enbridge, *Federal Carbon Charge* (link).
[16] Ontario Energy Board, *Historical Natural Gas Rates* (link).

- The federal government is now providing $5,000 incentives for customers to switch to high-efficiency electric heat pumps as part of its Greener Homes Grant.[17]

- The federal government is now providing an *additional* $5,000 in incentives for customers to switch from oil to high-efficiency electric heat pumps if they earn a median income or lower (e.g. $122,000 after-tax income for a family of 4 in Ontario) through the Oil to Heat Pump Affordability Program.[18]

- The federal government is now providing up to $40,000 in interest free loans, which can be put towards conversions to electric heat pumps, and not gas equipment, through the Greener Homes Loan.[19]

A typical homeowner in a gas expansion community would save approximately $20,000 with an electric heat pump versus gas heating over the lifetime of their heating equipment.[20] These savings mainly come from lower ongoing heating costs and cooling costs, which arise because electric heat pumps are more efficient at heating and cooling in comparison to traditional gas equipment paired with an air conditioner. As noted above, savings can also arise from lesser upfront costs. The $20,000 savings figure does not incorporate the benefit from interest-free financing available for heat pumps or the new $5,000 oil to heat pump incentive.

The actual savings will fluctuate depending on building characteristics, energy prices, and assumptions such as equipment costs. For instance, the savings from heat pumps will decline if, for example, gas prices drop or if a customer requires an upgrade to their electrical panel for the heat pump (which costs approximately $2,000).[21] On the other hand, savings from heat pumps will increase if gas prices increase, a house is heated with electric baseboards (because gas heating requires approximately $7,000 to add ducts whereas heat pumps can be installed without ducts),[22] or a customer with oil heating is eligible for $10,000 in federal rebates.[23] An expert analysis conducted by the Energy Futures Group found that heat pumps are still cheaper on a full lifetime basis even if various assumptions are adjusted to

---

[17] Government of Canada, *Canada Greener Homes* Grant (link).
[18] Government of Canada, *Oil to Heat Pump Affordability Program* (link).
[19] Government of Canada, *Canada Greener Homes Loan* (link).
[20] Dr. Heather McDiarmid, *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps*, August 2, 2022, p. 11 (link); For the difference in costs with the latest gas prices, see Ontario Clean Air Alliance, *Heat Pump Calculator for New Gas Communities*, link; see also Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, p. 23 (link).
[21] Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, p. 24 (link).
[22] Enbridge, *Response to Board Staff Interrogatory 4 in EB-2022-0249*, Exhibit I.STAFF.4 (link, pdf page 23).
[23] Government of Canada, *Oil to Heat Pump Affordability Program* (link); Government of Canada, *Canada Greener Homes* Grant (link).

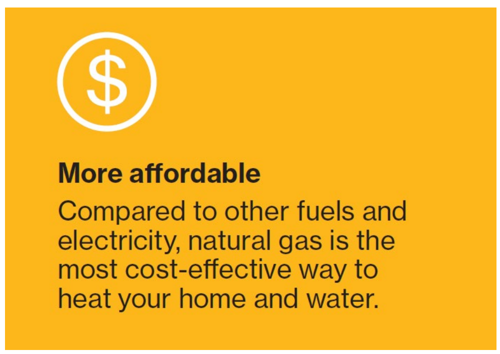
favour gas heating even outside community expansion areas where the 23 cents/m^3 surcharge applies.[24]

False and misleading representations

Enbridge is misleading customers into connecting to its gas system through deceptive marketing. These representations are being made in materials sent by mail, delivered at the doorstep, and posted at community events. A full package of these materials is attached. They are discussed below.

<u>Deceptive representation 1: That gas is the most cost-effective way to heat homes</u>

Various Enbridge marketing materials explicitly state that gas is the most cost-effective way to heat homes. That is false. As noted above, electric heat pumps are far less expensive for homes in Ontario. An example is excerpted below:

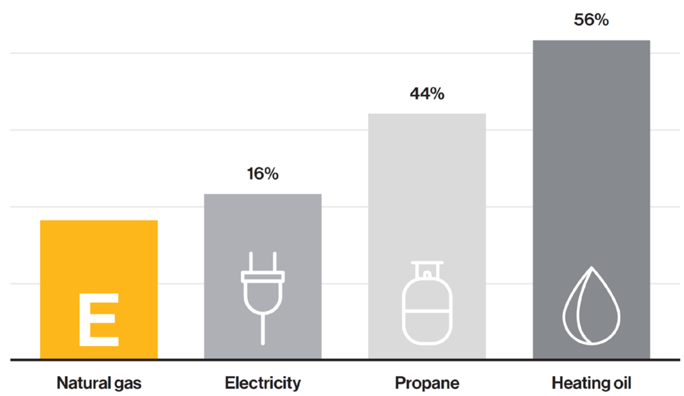


In addition, other materials may not *explicitly* say that gas is the most cost-effective way to heat homes, but they leave that general impression. This includes the "annual cost comparison" bar chart shown below:

[24] See, for example, the analysis in the following evidence at pages 23-24 of cost-effectiveness based on different assumptions: Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, pp. 23-24 (link).

Residential annual heating bills

Annual cost comparison: space and water heating*



In addition, the above bar chart explicitly states that gas heating is less expensive than electric heating, which is false. As noted above, electric heat pumps are much less expensive. Old-style electric baseboard heaters may be more expensive than gas, but that is not what Enbridge's materials state – either in the main body of the materials or the fine print. They state that annual heating is cheaper with "natural gas" versus "electricity." As another example, see the following letter sent to residents:

ENBRIDGE
Life Takes Energy

We're proud to energize the Township of Selwyn!

Dear Selwyn Resident,

Now's the time to apply for natural gas

We have some good news to share with you. Your address is identified as in scope for receiving natural gas shortly, and we want to make sure you're in the best position to connect as soon as possible. By signing up now, we'll be able to prioritize your service install as soon as the natural gas main is installed in front of your house. You may see us working on your street, including items such as survey stakes or locates.

If you're considering converting to natural gas, the earlier you apply the better as permits and locates can take time.

Refer to the Four-Step Process card when you're ready to apply, then visit **enbridgegas.com/savewithgas** to start your application. You're required to agree to the Terms and Conditions – either electronically during sign up at **enbridgegas.com/savewithgas**, or you can complete and email this to our Community Expansion Advisors at **ceapplications@enbridge.com** when the form is complete.

Unlock the value of natural gas

When compared to using electricity, propane or oil, natural gas could save you up to 54%* per year on home and water heating costs. Natural gas is also the most affordable way to run appliances like ranges, clothes dryers and barbecues.

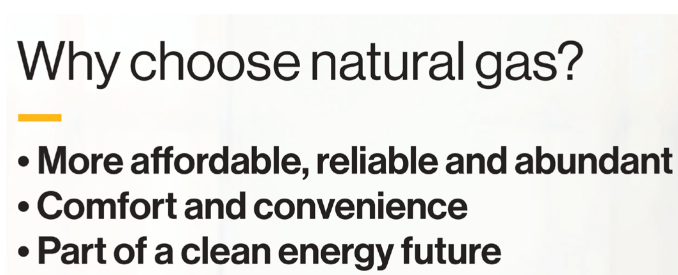
Various Enbridge marketing materials state that customers will save money by switching to gas. That may be true if a customer is switching from oil or propane. But it is highly misleading because it omits two important caveats: (a) customers could save far more by switching to an electric heat pump instead and (b) customers who already have a heat pump (which are admittedly few) would lose money by switching. An example is excerpted below:

<u>Deceptive representation 2: That methane gas is "low carbon" and "clean energy"</u>

Various Enbridge marketing materials use deceptive wording relating to heating by methane gas, including "low carbon" and "clean energy." They leave the general impression that methane gas can be accurately described with those terms and that switching to gas is environmentally conscious, which is false. Methane gas is a potent greenhouse gas that pollutes the environment and causes climate change when it is burned and when it leaks without being combusted.

Switching from propane or oil to gas may result in lower carbon emissions. But switching from electricity to gas will result in *higher* carbon emissions. And heating with heat pumps results in the lowest carbon emissions.

Two examples of deceptive representations are excerpted below:



Lower carbon emissions

Natural gas is cleaner than other fuels and can help reduce your home's carbon footprint.

Knowledge

Enbridge knows that the above representations are false, that gas is not the most cost-effective way to heat homes, and that gas is a potent greenhouse gas that contributes far more to climate change when used to heat homes in comparison to electricity.

Knowledge re cost-effectiveness of heat pumps

In 2020, Enbridge acknowledged in an Ontario Energy Board proceeding that customers would have higher annual heating costs with gas in comparison to high-efficiency electric heat pumps in gas expansion communities. This would have certainly come to the attention of upper-level Enbridge managers because it was discussed in a report of Ontario's Auditor General. The report contained the following passage:

> For example, in 2020, the OEB approved a utility proposal to construct a $10.1-million natural gas pipeline to connect new customers in North Bay. An Enbridge survey had indicated there was interest in doing so from homeowners who were using costly oil, propane or low-efficiency electric baseboards for heating. Once approved by the OEB, the project was eligible to receive a subsidy of $8.7 million to be paid by existing ratepayers. Without this subsidy the project was not economically feasible for the estimated 134 potential new natural gas customers. Even with an average subsidy of $65,000 per potential new customer, **the utility estimated that the potential customers would have higher annual heating costs than if high-efficiency electric heat pumps were used.** (emphasis added)[25]

Enbridge is also aware that heat pumps are more cost effective than gas from evidence in other proceedings it has been involved in and from a recent decision of the Ontario Energy Board, which approved incentives to switch from gas to electric heat pumps on the basis that this would be "a major benefit for customers."[26]

---

[25] Office of the Auditor General of Ontario, *Value-for-Money Audit: Reducing Greenhouse Gas Emissions from Energy Use in Buildings*, November 2020, p. 18 (link).

[26] Ontario Energy Board, *Decision and Order in EB-2021-0002*, November 15, 2022, p. 28 (link).

Knowledge that methane gas is not "low carbon" or "clean energy"

According to Enbridge's own evidence in Ontario Energy Board proceedings:

- The combustion of methane gas is responsible for approximately one-third of Ontario's greenhouse gas emissions;[27] and

- Gas heating results in far more carbon emissions than electric heating, even if the electric heating is with baseboards instead of high-efficiency electric heat pumps.[28]

Harm

Enbridge's deceptive representations cause significant harm whenever they succeed in convincing a customer to connect to Enbridge's gas system instead of lowering their bills with heat pumps. Most obviously, it will result in approximately $20,000 in unnecessary costs to the customer over the lifetime of the equipment.

In addition, customers are often effectively locked into gas when they connect to the gas system. For a customer to switch over to gas, they typically must spend thousands of dollars replacing their heating equipment. Enbridge estimates the cost at $5,000 for a home heated with oil and $12,000 for a home heated with electric baseboards.[29] This effectively locks those customers into gas because it is most cost-effective to switch to an electric heat pump when your existing heating equipment requires replacement in any event. That time of "natural replacement" will not occur until their new gas equipment comes to the end of its life in roughly 15 years. Stated differently, the switch to gas wastes money on gas equipment that could have been spent switching over to a heat pump instead.

There are negative impacts on competitors too. More people converting to gas means less demand for heat pumps. This negatively impacts heat pump manufacturers, distributors, and installer. It also negatively impacts companies that generate or transport electricity.

---

[27] Enbridge Evidence in Ontario Energy Board File #EB-2022-0200, Exhibit 1, Tab 10, Schedule 3, Page 2 (link)

[28] Enbridge Response to Interrogatories in EB-2019-0188, Exhibit I.ED.7, Attachment 1, Page 2 (link, pdf page 180).

[29] Enbridge, *Response to Board Staff Interrogatory 4 in EB-2022-0249*, Exhibit I.STAFF.4 (link, pdf page 23). According to Enbridge, customers can convert their existing propane furnace to burn methane gas for $600. However, these customers lose the benefit of securing new heating and cooling equipment and would need to incur future equipment replacement costs when their furnace and/or their air conditioner reaches the end of its life. They will also end up with higher heating and cooling costs.

Society as a whole suffers as well. If fewer heat pumps are installed, Ontario's carbon pollution will be higher and it will be more difficult and more expensive to meet our carbon reduction targets. The carbon impacts are particularly problematic because they will persist for the lifetime of the equipment in question. If a consumer installs a gas furnace instead of a heat pump today, that choice could continue to result in higher-than-necessary carbon pollution until 2040.

Temporary orders

Environmental Defence requests that the Commissioner apply for a temporary order to stop the harm described above. Enbridge forecasts connecting 3,855 customers to its gas system in these gas expansion communities alone over 2023 to 2025.[30] If a temporary order is not made, thousands of customers could connect to the gas system while this matter is under consideration, losing approximately $20,000 each on average.

We therefore request an order that Enbridge write to all customers in the gas expansion communities and provide information on the cost-effectiveness of electric heat pumps versus gas equipment for an average customer, including all lifetime costs (equipment, heating, and cooling costs), and specific details of the rebates available for customers from the federal government, with the content to be approved by the Commissioner.

In addition, a temporary order is warranted regarding ongoing marketing. We also request an order that all future marketing materials that refer to the price of gas versus other energy options indicate the comparative cost-effectiveness of electric heat pumps versus gas equipment for an average customer, including all lifetime costs (equipment, heating, and cooling costs), and specific details of the rebates available for customers from the federal government, with the content to be approved by the Commissioner.

Disclosure re other marketing

This request primarily focuses on the deceptive marketing to customers in community expansion areas as these are the only marketing materials that we have access to. However, it is likely that deceptive representations are being made to other potential customers. This likely includes broad-based marketing and materials used with other prospective homeowners inquiring about switching to gas as well as builders and subdivision developers considering which equipment to install in new construction. These other potential customers are important. Enbridge forecasts

---

[30] Enbridge Gas Inc., Answer to Interrogatory from Environmental Defence in Ontario Energy Board File # EB-2022-0200, Exhibit I.2.6-ED-94, p. 5, (link) (The forecast customers over 2021 to 2023 are 2,150).

connecting over 100,000 customers between 2023 and 2025 alone (with over 13,000 switching to gas and the remaining as new construction).

We therefore request that the Commissioner require Enbridge to disclose all materials with representations relating to potential savings arising from gas, including advertising and materials that Enbridge has provided to homeowners, builders, and subdivision developers.

Although the savings from heat pumps are highest in gas expansion areas where the 23 cents/m^3 charge applies, heat pumps are still much less expensive for the average customer outside these areas.[31] These other customers are very numerous and will still lose large sums if they end up purchasing gas equipment instead of electric heat pumps.

Conclusion

Enbridge's marketing materials combine both falsehoods about the true cost of heating with gas and deceptive greenwashing. Consumers are highly susceptible to these falsehoods and deceptive messages because heat pump awareness is very low among most Ontarians. We ask that the Commissioner commence an inquiry, require further disclosure from Enbridge on its other marketing materials, institute proceedings, seek interim orders to stop the ongoing deception, and request the maximum penalties, all for the sake of protecting consumers, competition, and the climate.

Keith Brooks
Programs Director
Environmental Defence

Attachment 1: Material required by s. 9 of the *Competition Act*
Attachment 2: Marketing material in community expansion areas

---

[31] Evidence of the Energy Futures Group in Ontario Energy Board File # EB-2022-0200, p. 23 (link); Dr. Heather McDiarmid, *An Analysis of the Financial and Climate Benefits of Electrifying Ontario's Gas-Heated Homes by Installing Air-Source Heat Pumps*, August 2, 2022, p. 6 (link).

COMMISSIONER OF COMPETITION

IN THE MATTER OF the *Competition Act,* RSC 1985, c. C-34;

AND IN THE MATTER OF an application under s. 9 of the *Competition Act* to institute an inquiry into deceptive marketing by Enbridge Gas Inc.

DECLARATION OF SCOTT HORTOP

I, Scott Hortop, of the Municipality of Mississippi Mills in Lanark County and in the Province of Ontario, hereby solemnly declare and affirm:

1. My address is as follows: Scott Hortop, c/o Climate Network Lanark, . My email address is

2. I believe Enbridge Gas Inc. has contravened the *Competition Act* as set out in the letter from Keith Brooks to the Competition Bureau dated June 19, 2023. The nature of the contravention, the grounds for the making of the order, the offence, and the evidence supporting my opinion can be found in that letter.

Declared remotely by the declarant in the Town of Almonte, in the Province of Ontario, before me at the City of Toronto in the Province of Ontario, on June 19, 2023, in accordance with O. Reg 431/20, Administering Oath or Declaration Remotely.

A Commissioner for taking affidavits, etc.

SCOTT HORTOP