Appendix 5

Load Projections

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1 | Introduction

Load projections, based on guiding principles and planning assumptions, are the potential future energy demands for natural gas and electricity that Manitoba Hydro may need to supply. The guiding principles shape the overall approach to developing the load projections, while the planning assumptions provide the foundation for building the load projections. The load projections developed for the 2025 IRP include assumptions of how Manitobans might transition to a net-zero economy by 2050.

To address the uncertainty surrounding the amount and pace of change in both electricity and natural gas consumption, Manitoba Hydro developed three load projections extending to 2050. These load projections explore different combinations of potential government actions and customer decisions.

Feedback from participants in Round 1 Engagement supported the planning assumptions and the three proposed load projections. Participants generally agreed that the assumptions captured the most influential factors and the projections offered a broad range of possible energy futures for Manitoba. Participants also shared that the load projections should reflect what is required to eliminate fossil fuels in the transportation and space heating sectors by 2050.

In response, Manitoba Hydro included analysis of a load projection sensitivity to examine how provincial energy demand might change if fossil fuels were eliminated from ground transportation and space heating in Manitoba.

This appendix outlines the guiding principles, approach, and methods used to develop the 2025 IRP load projections. It also provides an overview of the three projections, details the planning assumptions for each, and describes the added load projection sensitivity developed in response to Round 1 Engagement.

2 | Guiding Principles

Guiding principles were established to support the development of load projections that reflect a wide range of possible electricity and natural gas consumption futures in Manitoba. These principles ensure the load projections are both realistic and capable of representing a wide range of future energy outcomes. The guiding principles for developing the 2025 IRP load projections were:

- Capture a **broad range of potential futures** for both electricity and natural gas.
- Develop a **baseline projection** that assumes limited changes in how Manitobans use electricity and natural gas, and based on government actions that are already implemented.
- Ensure **two of the three load projections reflect potential loads required to support a net-zero economy in Manitoba by 2050, illustrating** different pathways to achieve a net-zero economy by 2050.
- **Leverage key learnings from the 2023 IRP and other ongoing planning work** to develop planning assumptions and methodologies.
- **Limit the premature removal of existing systems** that have not reached end of useful life.

In addition to the guiding principles outlined above, several other considerations shaped the planning assumptions used to develop the load projections. Planning assumptions reflect the expectation that Manitobans' energy behaviours and consumer habits remain consistent with current trends (e.g., no widespread shifts from private vehicles to active or public transit; building development remains largely consistent with existing codes, with minimal changes affecting heating demand), aside from improvements in energy efficiency. They also assume steady, demand-aligned growth in industries and skilled labour needed for the energy transition—avoiding excessively overbuilding capacity that may not be sustained. For example, the planning assumptions do not assume an unsustainable surge in specialized trades—such as heat pump contractors—that would later become unnecessary once peak installation needs decline post 2050.

The load projections also reflect how Manitobans might transition to a net-zero economy by 2050. The province had not published an official net-zero definition when IRP analysis began; however, within the 2025 IRP, "net-zero economy" refers to a future state where all anthropogenic (i.e., human-caused) greenhouse gas (GHG) emissions in Manitoba's entire economy are balanced to zero on an ongoing cumulative basis. This balance is achieved through a combination of actions: reducing emissions—such as through electrification and other means—and using offsets or removals from the atmosphere to "net-out" any remaining emissions from 2050 onwards. The definition of net-zero within the 2025 IRP is consistent with the definition used by the federal government.[1]

[1] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

Additional guiding principles were developed for the two load projections that supported a net-zero economy by 2050:

- Efforts will be made to **reduce GHG emissions across all sectors**.
- A net-zero economy will have **less reliance on fossil fuels**.
- To achieve a net-zero economy, **a made-in-Manitoba approach was used** – this means that Manitoba would not depend on sources outside of the province from 2050 onwards for any GHG reductions, removals, or non-fossil fuels.
- **Public safety will not be put at risk to achieve a net-zero GHG emissions economy by 2050 in Manitoba**, acknowledging that some back-up fuels, fossil or non-fossil, may be needed for essential functions.
- When **uncertainty is high** in analysis, a conservative approach is used (e.g., GHG emission reductions are underestimated rather than overestimated), in alignment with the GHG accounting principle of conservativeness.[2]

The above guiding principles align with the federal government's roadmaps and Manitoba's Expert Advisory Committee's GHG emission reduction goals and exclude net-zero economy pathways that increase production of hydrogen from natural gas (blue and grey hydrogen and/or methane pyrolysis).[3,4]

Under these guiding principles for achieving a net-zero economy, Manitoba Hydro assumes concerted and widespread efforts to reduce both combustion and non-combustion GHG emissions in Manitoba's economy. This includes reducing reliance on fossil fuels within transportation and industrial sectors through a variety of different means, implementing technologies and processes to reduce non-combustion GHG emissions, while following the made-in-Manitoba approach to GHG emissions reductions and removals.

Specifically, the made-in-Manitoba approach mitigates the risk of uncertainty with extra-provincial supply of net-zero compatible fuels and GHG emissions offsets while providing a more realistic net-zero pathway for Manitoba compared to pathways that rely on imported GHG emission solutions. A made-in-Manitoba approach also allows for the inclusion of upstream GHG emissions and electricity impacts (as it relates to the electric load projections) in the analysis and encourages the consideration of locally sourced, sustainable solutions.

[2] https://ghginstitute.org/2022/01/27/the-overlooked-mystery-of-the-missing-ghg-accounting-principle/

[3] https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/achieving-net-zero-emissions-electricity-generation-discussion-paper.html

[4] https://www.gov.mb.ca/asset_library/en/eac/eac_carbon_savings_report2022.pdf

3 | Approach & Methodology

3.1. Approach

Each load projection was developed to align with the overall pace of change as shown in Figure A5.1 below. The 1-Baseline load projection reflects minimal changes in how Manitobans use electricity and natural gas, based primarily on current government actions, market conditions, and technology. The 2-Medium and 3-High projections explore the potential loads required for higher levels of economic growth, economic development, and to support a net-zero economy by 2050, each representing a different pathway towards that goal.

Baseline Load Projection
Assumes minimal changes from current policies and customer decisions.

Medium Load Projection
Assumes moderate impact from government actions and customer decisions and achieves economy wide net-zero by 2050.

High Load Projection
Assumes significant impact from government actions and customer decisions and achieves economy wide net-zero by 2050.

Figure A5.1 – Load Projection Descriptions

These projections are built on planning assumptions, which have been revised based on learnings from the 2023 IRP and ongoing planning. The planning assumptions vary based on the pace of change assumption described above, Figure A5.2 provides a high-level summary of the planning assumptions by projection, with further details how they impact electricity and natural gas demand provided later in this appendix.

1 - Baseline	2 - Medium	3 - High
Slightly lower economic growth	Average economic growth	Slightly higher economic growth
Natural gas remains an unrestricted option for Manitobans	Strategic use of natural gas to mitigate peak load implications	Restricting the use of natural gas
Limited industrial economic development and decarbonization	Medium levels of industrial economic growth and decarbonization	Higher levels of industrial economic growth and decarbonization
No use of negative GHG emissions technologies	Use of negative GHG emission technologies	Use of negative GHG emission technologies
-	Achieve economy wide net-zero by 2050	Achieve economy wide net-zero by 2050

Figure A5.2 - Planning Assumption Description by Load Projection

Manitoba Hydro undertook analyses to identify planning assumptions for both the 2-Medium and 3-High load projections to attempt to understand what the electrical and natural gas demand in a net-zero economy in Manitoba might look like. These assumptions were based on reasonable and appropriate high-level boundaries based on the guiding principles. Manitoba Hydro makes no claims or guarantees that the net-zero economy analysis within the 2025 IRP is the best, most efficient, or most effective means to support a net-zero economy. The primary function of the analysis was to understand the load impacts of potential pathways to a net-zero economy in Manitoba. It is possible that varied combinations of assumptions could result in similar load projections.

For 2025 IRP analysis, both net-zero grid by 2035 and net-zero economy by 2050 targets are assumed to be achieved on an ongoing cumulative basis. When undertaking a GHG emissions balance analysis to estimate whether a net-zero grid (from 2035 onwards) or net-zero economy (from 2050 onwards) has been achieved, Manitoba Hydro assumes average/normal weather and average hydrologic flow conditions. Annual fluctuations above ("net-positive") and below ("net-negative") net-zero GHG emissions, due to non-normal conditions, are assumed to cumulatively average to net-zero over the long term.

3.2. Methodology

For the 2025 IRP, Manitoba Hydro prepared 25-year load projections out to 2050 to provide potential long-term future electrical demand and natural gas demand requirements in Manitoba. Three load projections were developed using a series of methods and then built upon using a foundation of planning assumptions.

Manitoba Hydro continues to advance its forecasting methodology, and this section describes the methodology used to develop the three load projections. Manitoba Hydro applies industry standard forecast models by customer sector across all projections, including econometric modelling, end use forecasts, and individual customer forecasts. The following methods, except for net-zero economy specific methods, were applied consistently across all three load projections to develop the individual projection. The net-zero economy specific methods were applied to the 2-Medium and 3-High load projection, but not to 1-Baseline load projection.

3.2.1. Econometric Modelling

Econometric modelling leverages weather adjusted historic consumption trends, considers future predictions for economic factors including population, income, gross domestic product (GDP), and energy price, and helps project future electricity and natural gas load for residential, commercial, and industrial sectors. Econometric modelling used for residential forecasts also includes inputs from an end use model, which provides the percentage of homes heating with electricity, and the econometric model used for large industrial customers projects long-term growth starting in the sixth year of the forecast to complement the individual customer forecasts utilized for the first five years. The models used are consistent across all load projections, but the individual economic inputs vary.

3.2.2. End Use Forecast

Manitoba Hydro employs an end use forecast methodology for the residential basic sector, referred to as the residential end use forecast, to complement the econometric model. The primary objective of this forecast is to project the space heating, water heating, and air-cooling systems of residential customers. Projections are separated into groups by new or existing dwelling, by region, and by dwelling type. Regions within the end use model are identified as one of three areas: Winnipeg, due to its denser population in Manitoba; areas outside of Winnipeg where natural gas is available; and, areas outside of Winnipeg where natural gas is not available. Dwelling types are separated into single detached, multi-attached, and apartments.

Econometric equations are used to forecast the number of electric space heating systems in new single detached and multi attached dwellings by region. The results of the 2023 Residential Energy Use Survey serve as a basis for projections and provide the average age of space heating and water heating systems in the province. The quantity of annual replacements of each existing heating system type is then estimated and the type of heating systems installed depend on the load projection assumptions, which include fuel switching.

All three load projections assume different approaches to decarbonization and decentralization, with varying levels of impact on Manitoba Hydro's systems. New technology adoption models were used to determine the rate by which and when conversions to new technologies take place.

3.2.3. Individual Customer Forecast

In the large industrial customers category, there are 11 companies represented as 28 customers covering five industry sectors. Each customer is forecasted individually based on information collected on individual operating plans, including short-term expansion or contraction plans. The sources of information are derived from industry news and publications, company prospectuses, and from Manitoba Hydro's key and major account advisors. The information collected is used in the preparation of company specific short-term forecasts for committed projects. The short-term plans are forecasted to occur within the first five years.

3.2.4. Hourly Load Shapes

The evolving energy landscape will transform the way Manitobans use electricity and alter the relationship between average and peak electrical demand in the future. Key drivers of this shift include the electrification of transportation and space heating, as well as increased adoption of customer-side technologies such as energy efficiency, demand response, self-generation and energy storage. To capture the respective system peak impacts from these technologies, hourly load shapes were developed and incorporated within the demand projections.

The hourly load shapes are a model that characterizes one year (8,760 hours) of typical hourly energy demand of a particular rate class based on five years of historical interval data collected from Manitoba Hydro's load research sample meters. An hourly load shape has been developed for each rate class using a rank and average method, and where applicable, the class relationship to weather. The hourly load shape indicates typical rate class hourly behaviours and helps to understand the rate class contribution at the time of system peak, as well as individual class peak demands. The hourly load shapes support the development of the 2025 IRP as the hourly distribution defines the coincident system peak and supports cost allocation and rate design studies for each of the rate classes. Hourly load data is also required for preparation of the resource optimization model inputs, as discussed in Appendix 7.1 - Modelling & Analysis Approach.

3.2.5. Miscellaneous Sectors

The miscellaneous sectors consist of the smaller sales sectors that make up less than 1% of electricity consumed in Manitoba and include seasonal customers, flat rate water heating and area and roadway lighting. These sectors were forecast by analysis of the changes in the number of customers or services and average use per customer or service. Growth rates were applied based on history and a best estimate as to what the future will bring.

3.2.6. Net-Zero Economy

Additional government actions, improvements to market conditions, and/or technological advancements are required for a net-zero economy to be achieved. To reflect the requirements of a net-zero economy future, the 2-Medium and 3-High load projections include additional electric loads. These loads account for potential incremental increases in Manitoba's biofuel and hydrogen production, industrial carbon capture & sequestration (CCS) technology, and negative GHG emission actions. The methods used to estimate these additional electric loads were informed by a GHG emissions balance analysis, outlined as follows:

1. Manitoba Hydro assumed that Manitoba biofuel production achieves its full sustainable potential by 2050. Incremental **local biofuel production load was included in both the 2-Medium and 3-High load projections**.

2. Manitoba Hydro assumed that potential incremental hydrogen end-uses in Manitoba included hydrogen fuel-cell vehicles. **Local hydrogen production load for use other than electricity generation was included in the 2-Medium and 3-High load projections.**

3. Manitoba Hydro assumed Manitoba's largest industrial natural gas consumers would deploy CCS on their production by 2050 and continue to use natural gas. **Industrial CCS load was included in the 2-Medium and 3-High load projections in 2049/50.**

4. Manitoba Hydro estimated residual combustion GHG emissions in Manitoba's economy in 2050 based on the load projection's planning assumptions (i.e., assumptions related to economic growth, decarbonization of space heating and transportation, energy efficiency, and industrial decarbonization) as well as the above biofuel, hydrogen, and CCS assumptions.

5. Manitoba Hydro estimated residual non-combustion GHG emissions in Manitoba's economy in 2050 based on estimates of GHG emission reduction potentials from each of Manitoba's non-combustion source categories.

6. Then, after estimating the residual combustion and non-combustion GHG emissions, Manitoba Hydro assumed there would be an electric load associated with netting the residual economy-wide GHG emissions to zero that would need to be quantified. **Negative GHG emissions load was included in the 2-Medium and 3-High load projections in 2049/50.**

When estimating GHG emissions in a net-zero economy, it is assumed that the combustion of biomass does not typically produce any net human-caused (anthropogenic) GHG emissions and Manitoba Hydro does not include biofuel GHG emissions in the definition of net-zero targets, as is common with industry assumptions.[5] Further discussion can be found in Appendix 7.1 - Modelling & Analysis Approach.

[5] https://www.tandfonline.com/doi/epub/10.1080/17583004.2022.2067456

3.2.6.1. Fuels as Back-Up Energy Sources

To quantify the potential electric load that might be required to support negative GHG emission actions, it was necessary to estimate 2050 GHG emissions from combustion sources, specifically fossil fuel use, in Manitoba.

In alignment with the guiding principles, Manitoba Hydro assumed for the 2025 IRP that some fossil fuels may be required in a net-zero economy future for, at a minimum, specific safety-related applications including electricity system reliability. Analysis indicates that fuel-based—fossil and non-fossil—generation will continue to play an important role in maintaining Manitoba's grid reliability well beyond 2050. Further details on this analysis are provided in Appendix 7.2 - Modelling & Analysis Results.

There are many current energy applications where fuel and fuel storage are the most practical energy solutions, as they provide reliable energy in remote locations and reliable back-up energy for emergency use. For example:

- Diesel storage tanks at the electricity generators at four northern off-grid communities: Brochet (Barren Lands First Nation), Lac Brochet (Northlands Denesuline First Nation), Tadoule Lake (Sayisi Dene First Nation), and Shamattawa (Shamattawa First Nation). Manitoba Hydro can keep enough fuel in these tanks to provide electricity to those communities for over two years.
- Nearly all hospitals have back-up fuel tanks which can power back-up electricity generators in case the electrical grid experiences an outage.
- The electricity grid, where having large stockpiles of fuel on-hand to be quickly converted to electric energy when needed can be invaluable for overall system reliability.

The use of fuels as back-up energy sources (and for other purposes), specifically fossil fuels, will result in residual combustion GHG emissions in Manitoba's economy that will need to be balanced in a net-zero economy future. As such, there is a potential electric load required to support negative GHG emissions in netting residual GHG emissions from fossil fuels to zero.

3.2.6.2. Non-Combustion GHG Emission Reductions

To quantify the potential electric load that might be required to support negative GHG emission actions, it was necessary to also estimate 2050 GHG emissions from Manitoba's non-combustion sources.

Currently, 42% of Manitoba's GHG emissions are from non-combustion sectors, as detailed in Appendix 3 - Existing System. Reducing non-combustion GHG emissions is typically unrelated to energy consumption or fuel choices. As such, from a theoretical, economic, and technological perspective, the reduction of non-combustion GHG emissions can be challenging without major market changes or disruptions.

Manitoba Hydro reviewed publicly available literature and the Government of Canada's GHG emission aspirations to estimate GHG emissions reduction potentials from Manitoba non-combustion sources.[6] Manitoba Hydro assumed that, in alignment with the guiding principles, there would be widespread and concerted efforts to support non-combustion GHG emission reductions in Manitoba. Manitoba Hydro recognizes that non-combustion GHG emission reductions beyond what was assumed for the 2025 IRP load projections are technically possible, and GHG emissions reductions beyond what was assumed may reduce the required negative GHG emission electric loads.

Table A5.1 summarizes the non-combustion GHG emission reduction assumptions Manitoba Hydro incorporated into the 2-Medium and 3-High load projections. Economy-wide GHG projections assumed linear GHG emission reductions in each non-combustion sector between 2030 and 2050, with the exception of industrial process GHG emissions, which are assumed to occur in 2050. Manitoba's non-combustion sectors are not assumed to stop releasing GHG emissions by 2050 – residual non-combustion GHG emissions would be balanced in a future net-zero economy through negative GHG emissions technology.

[6] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html

Table A5.1 – Assumed Manitoba Economy Non-Combustion GHG Emissions Reductions

GHG emissions Source[7]	2022 GHG emissions (kt CO_2e)	2050 GHG emissions (kt CO_2e)	Assumed Reduction From 2022 (% [kt CO_2e])
Fugitive Sources[8]	642	192	70% [449]
Industrial Processes	943	632	33% [311]
Agriculture: Enteric Fermentation	2,462	1,994	19% [468]
Agriculture: Manure Management	689	517	25% [172]
Agriculture: Soils	2,365	1,655	30% [709]
Agriculture: Liming, Urea Application and other Carbon-Containing Fertilizers	352	246	30% [106]
Agriculture: Field Burning	22	11	50% [11]
Waste	1,354	677	50% [677]
Total	**8,829**	**5,925**	33% [2,903]

The following sub-sections provide rationale for the assumptions made when estimating GHG emissions reductions for each non-combustion source category.

Fugitive Sources

At the time of developing GHG emission estimates and assumptions for the 2025 IRP, the Government of Canada was developing regulations to reduce fugitive methane from the oil and gas sector to 75% of estimated levels in 2012, by 2030.[9] Manitoba Hydro assumed that realized GHG emissions reductions were evenly distributed across Canada, resulting in a 70% reduction observed in Manitoba by 2050 as compared to 2022 levels.

Industrial Processes

Manitoba Hydro assumes that certain, hard-to-abate industries (e.g., cement, steel, or chemicals) within the province are good candidates for carbon capture & sequestration (CCS), and that these industries pursue CCS rather than pursuing other forms of decarbonization. This assumption conservatively results in a 33% reduction from 2022 levels in this GHG emissions category.

[7] Refer to Canada's National Inventory Report Part 3 for further details and information on how non-combustion GHG emissions are categorized.
[8] Note: Flaring is not included in this value as it is a combustion GHG emission; however, flaring is included in the International Panel on Climate Change sector, as presented in the National Inventory Report.
[9] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/reducing-methane-emissions/faster-further-strategy.html

Agriculture

Non-combustion agricultural activities are diverse and significant sources of GHG emissions in Manitoba. Assumed GHG emission reductions varied by sub-category:

- **Enteric fermentation** – Due to the diffuse nature and predominantly family-farm organization of ruminant livestock husbandry in Manitoba, realizing the full technical potential of enteric fermentation GHG emission reductions is challenging. Therefore, for conservativeness, Manitoba Hydro only assumed a 19% reduction in GHG emissions from enteric fermentation.
- **Manure management** – Manitoba Hydro has assumed some degree of biomethane production from anaerobic digestion of livestock manure. As such, conservatively, it has been assumed that a 25% reduction in GHG emissions from manure management will be observed.
- **Soils and fertilizer applications** – At the time of developing GHG emission estimates and assumptions for the 2025 IRP, the Government of Canada had an aspirational goal of reducing the required fertilizer inputs in agricultural fields by 30% below 2020 levels.[10] Manitoba Hydro assumes that this reduction is fully realized and that the GHG benefits are distributed evenly across Canada. Therefore, Manitoba Hydro assumed a 30% reduction in GHG emissions from fertilizer application.
- **Field burning** – While a relatively small source of GHG emissions in Manitoba, Manitoba Hydro assumed that fuel procured for both bioenergy carbon capture and sequestration (BECCS) and biomass generation units would reduce the amount of crop residue burned in the field. Additionally, Manitoba Hydro assumed greater uptake of conservation tillage practices where crop residue and other organic plant matter is at least partially left on agricultural fields rather than being burned. This allowed Manitoba Hydro to assume a 50% reduction in GHG emissions from field burning in the province.

Waste

At the time of developing GHG emission estimates and assumptions for the 2025 IRP, the Government of Canada released the draft regulations intended to reduce methane emissions from the waste sector to 50% below 2019 levels by 2030.[11] Manitoba Hydro assumes that these 50% reductions were evenly distributed across Canada and that these regulations would result in a 50% decrease below 2022 levels in Canada, but by 2050. The extended timeframe for these GHG emissions reductions was assumed for conservativeness. However, for electrical demand and annual negative GHG emissions forecasting within the 2025 IRP, the rate of reduction is less important than the annual value of the residual GHG emissions occurring in 2050.[12]

[10] https://agriculture.canada.ca/en/department/transparency/public-opinion-research-consultations/share-ideas-fertilizer-emissions-reduction-target/discussion

[11] https://gazette.gc.ca/rp-pr/p1/2024/2024-06-29/html/reg5-eng.html

[12] From a climate science and climate change perspective, Manitoba Hydro acknowledges and recognizes that cumulative GHG emissions over a given study period are more important to understand than annual GHG emissions; however, this exercise was completed in order to estimate annual electrical energy and peak demand requirements

4 | Load Projections

4.1. Customer Electric and Natural Gas Demand Projections

Using the previously described methodology, individual demand for each load projection was developed. Figure A5.3 shows the annual electrical energy needs over the study period for each load projection, while Figure A5.4 shows annual peak electrical demand for each load projection. The planning assumptions are described in the next section of this appendix.

In all projections, customers require more electricity in the future as they adopt electric vehicles (EVs) and start to use more electricity in aggregate to heat their homes and businesses.[13] This is most pronounced in the 3-High load projection where, by the end of the study period, peak customer demand and annual energy consumption will be approximately triple what it is today.

The following electrical and natural gas demand projections are net of Efficiency Manitoba's energy efficiency projection and serve as the inputs for the resource optimization modelling outlined in Appendix 7.1- Modelling & Analysis Approach.

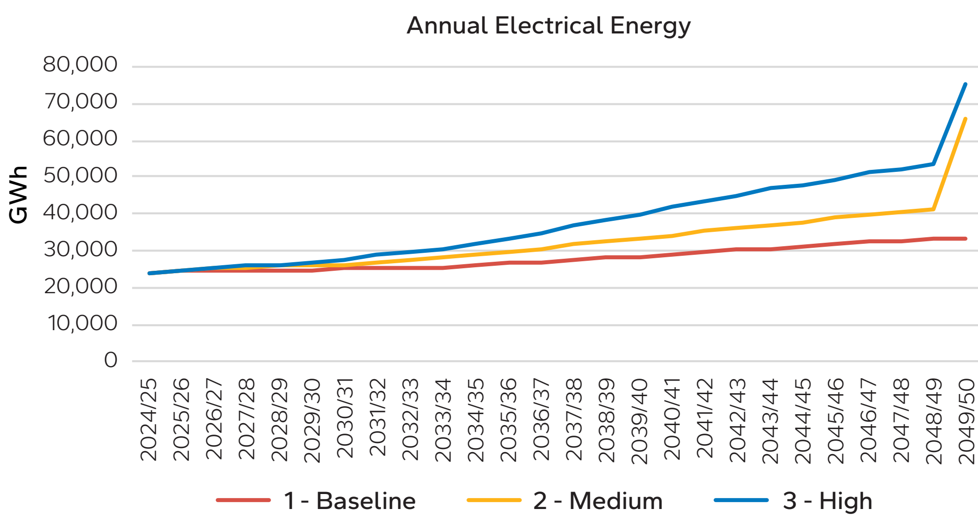


Figure A5.3 - Load Projections – Electrical Energy

[13] Note: Some customers who already use electricity to heat their homes are assumed to use less due to the adoption of energy efficiency technologies like cold-climate air source heat pumps.

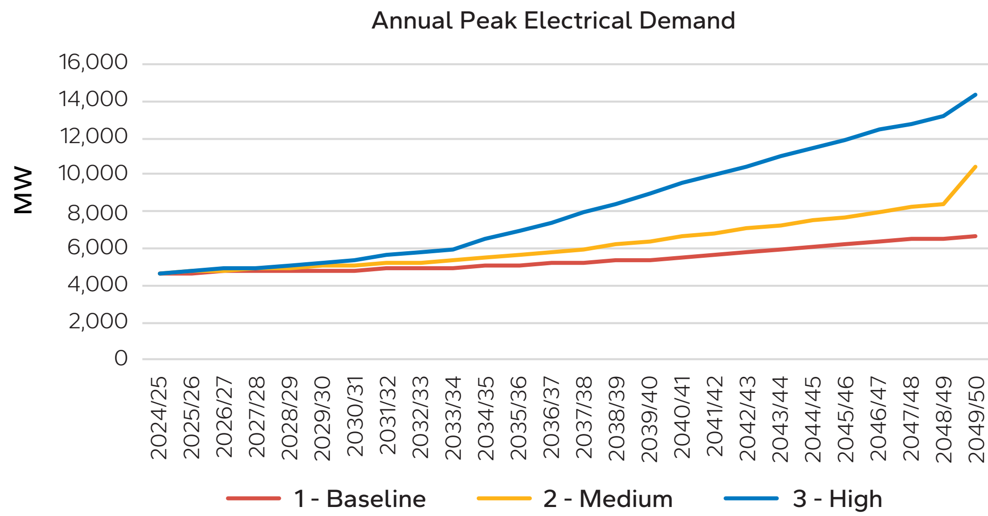


Figure A5.4 - Load Projections – Electrical Demand

Figure A5.5 shows the total annual natural gas consumption for each load projection. As the assumptions related to decarbonization become more aggressive in the 2-Medium and 3-High load projections, natural gas consumption decreases.

While annual natural gas consumption may decline, this does not necessarily translate to how the natural gas system needs to be designed. Gas distribution systems are planned to deliver firm customer demand on a "design day" (the coldest day) while maintaining adequate pressure for reliable service.

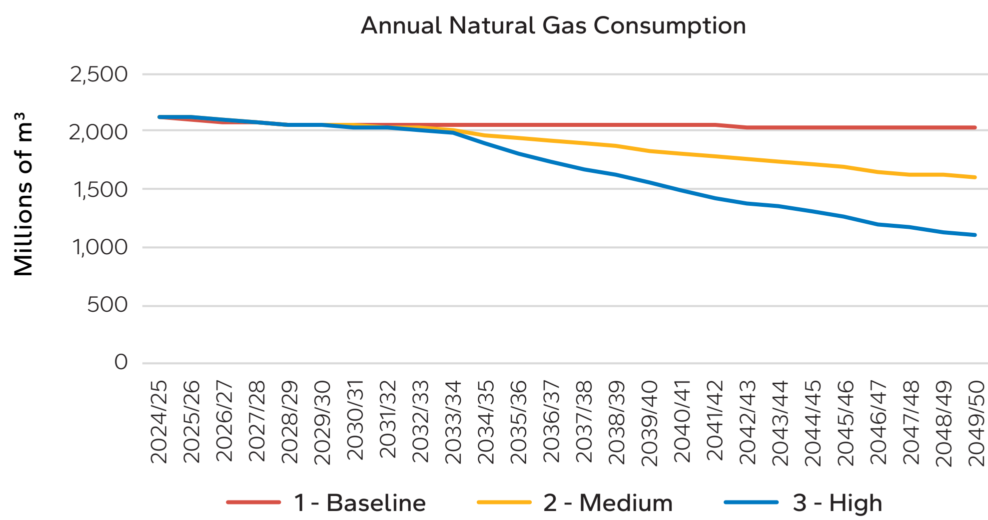


Figure A5.5 - Load Projections – Natural Gas Demand

5 | Planning Assumptions

Manitoba Hydro developed load projections by altering values for certain planning assumptions. The following graphic in Figure A5.6 represents the key planning assumptions along with a slider illustrating the changes in how each assumption was included across each load projection. The sliders are designed to represent the magnitude of change within each planning assumption but not identify the magnitude of impact across each planning assumption.

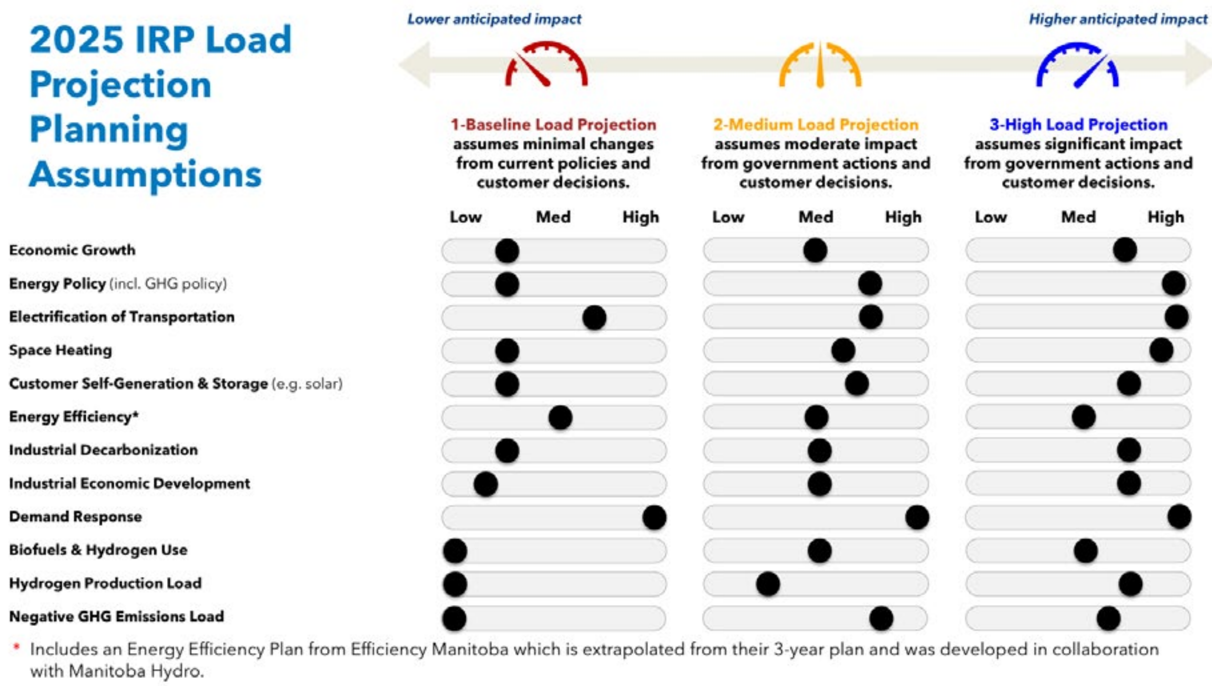


Figure A5.6 - Planning Assumptions

5.1. Economic Growth

Economic growth is subject to uncertainty with factors such as global conflicts, financial conditions, and trade dynamics serving as examples of unpredictable influences. Due to the long study period of the 2025 IRP, rather than trying to predict economic cycles and specific factors, economic growth has been simplified to average growth rates over the study period.

Manitoba Hydro uses independent consultant economic forecasts to establish economic growth rates. Growth rates are estimated to project key forecast inputs, including population, real gross domestic product (GDP), and income, which are used to support the three load projections. For each of the 13 previous forecast cycles, annual growth rates were calculated using both the most recent 5 years and the most recent 20 years of historical data. From these, three metrics were derived for each input: the average of the 5-year and 20-year growth rates, the minimum of the two, and the maximum of the two. These values were then used to guide the projection of forecast inputs over a 20-year horizon. For the first 5 years, each input was assumed to grow at the 5-year average, minimum, and maximum growth rates. For the remaining 15 years, the 20-year average, minimum, and maximum growth rates were applied. This approach was designed to reflect both short-term and long-term trends while accounting for variability in historical growth. Forecast inputs were assigned differently across the three load projections: the minimum growth was used for 1-Baseline load projection, the average growth for the 2-Medium load projection, and the maximum growth for the 3-High load projection. A summary of the assumptions used for each load projection is provided in Table A5.2 below.

Table A5.2 - Economic Growth Assumptions by Projection

1 - Baseline Load Projection	2 - Medium Load Projection	3 - High Load Projection
Real GDP: 1.52 %	Real GDP: 1.77 %	Real GDP: 2.22%
Manitoba Population: 1.0 %	Manitoba Population: 1.06%	Manitoba Population: 1.24%
Income: 3.29 %	Income: 3.74%	Income: 4.34%

An example of how these assumptions directly impact demand projections includes the number of new dwellings constructed each year to meet population needs. In addition, the economic growth assumptions indirectly affect the demand projections related to other planning assumptions. For the decarbonization of transportation assumptions, total vehicle sales are related to population growth, and for the space heating planning assumptions, new installations are also related to population growth and real disposable income.

5.2. Energy Policy and Energy Prices

5.2.1. Energy Policy

Energy policy serves as a foundational input, primarily influencing planning assumptions related to transportation and space heating decarbonization. These assumptions align with the overarching load projection descriptions outlined in Figure A5.1. Appendix 4 – Policy Landscape provides an overview of the relevant policies considered.

Energy policy is also reflected across other planning assumptions, including energy efficiency, industrial decarbonization, economic development, biofuels, hydrogen, and negative GHG emissions load.

5.2.2. Energy Prices

The gas and electric load forecasting methodology is grounded in econometric models, with electricity and natural gas prices serving as a fundamental input. These prices influence forecasted electricity demand across sectors and play a key role in determining the market share between electric and natural gas space heating, particularly in new construction, where fuel choices are made during the building phase. Over the long term, energy prices shape both technology adoption and demand patterns. Manitoba Hydro incorporates both internal and external energy price forecasts for electricity and natural gas, capturing price trends and market expectations. These nominal price forecasts are later adjusted for inflation to obtain real price paths consistent with long-run economic conditions. 1-Baseline load projection assumes relatively lower prices over time, while 2-Medium and 3-High load projections reflect progressively higher price projections. This framework ensures consistency in long-term demand modeling across all load projections.

Energy price forecasts are commercially sensitive information and therefore not disclosed in this report.

5.2.3. Carbon (GHG Emission) Price

All load projections include an assumption on carbon price that incorporates the federal government's legislated nominal increases in carbon price to 2030 (see Appendix 4 - Policy Landscape for more details). Beyond 2030, a reference case projection was used for all projections where the carbon price reaches $170/t CO_2e nominal by 2030/31 and then proceeds to stay constant in real dollars (i.e., maintains its value with inflation). While the federal government has not specifically indicated it would tie the carbon price to inflation, it is assumed either this would be the case post-2030/31, or comparable nominal dollar increases would be applied to maintain a consistent carbon price signal. Carbon pricing plays an indirect but meaningful role in the load forecasting process by influencing relative energy costs. Specifically, Manitoba Hydro incorporates carbon pricing into the calculation of the gas-to-electricity price ratio for high-efficiency furnaces,[14] which in turn affects the projected market share of electric space heating systems in new dwellings. As electricity becomes more cost-competitive due to carbon pricing, Manitoba Hydro anticipates higher adoption of electric heating, leading to increased residential electricity demand over time.

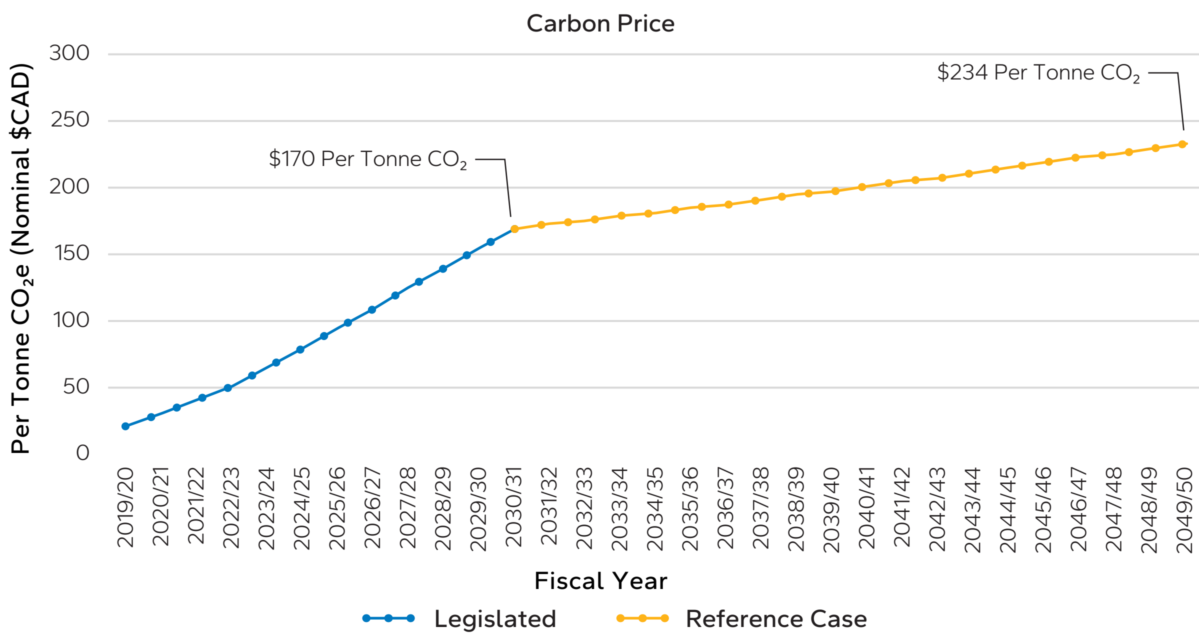


Figure A5.7 – Carbon Pricing Projection

[14] https://www.hydro.mb.ca/docs/resources/home-space-heating-costs-en.pdf

5.3. Decarbonization of Transportation

All three load projections assumed zero GHG emissions vehicle (ZEV) growth across all vehicle categories. The methodology to develop the ZEV demand projections is consistent across each load projection and is the product of the following factors:

- **ZEV Sales Targets:** The federal government's ZEV sales targets, as described in Appendix 4 – Policy Landscape, have been reflected for passenger cars/light trucks in all projections and for medium duty and heavy duty trucks in the 3-High load projection.
- **Vehicle Type:** Ratios were estimated using historical data supplied by Statistics Canada and Manitoba Public Insurance on vehicle purchases and registrations per year in Manitoba. Vehicle types include passenger car, light truck (including SUVs), medium-duty truck, heavy-duty truck, and bus.
- **Annual Electricity Consumption:** The distance driven per vehicle type and the associated electricity consumption.
- **Total Vehicle Sales:** Future trends in vehicles sales are projected based on assumptions from recent relevant literature applied to Manitoba, as well as population growth assumptions for each projection.
- **ZEV Sales %:** ZEV sales as a percentage of total sales are adjusted for each projection based on the level of decarbonization assumed.

The ZEV uptake in the passenger car, light truck, and bus categories was assumed to be 100% EVs while the ZEV uptake in the medium and heavy truck categories was assumed to be mostly EVs. For the medium and heavy truck categories it was also assumed that hydrogen fuel-cell vehicles would be used in certain applications where EVs were not viable options, in both the 2-Medium and 3-High load projections beginning in 2034/2035. This is consistent with Manitoba Hydro's guiding principles by acknowledging that certain activities in Manitoba's economy are more conducive to fuel-based energy use. In the 3-High load projection, about 16,000 medium and heavy-duty hydrogen fuel cell vehicles are assumed to be on the road in 2050.

Hydrogen used in transportation is part of a year-round supply chain for medium- and heavy-duty trucks, and its production affects peak electricity demand. The peak demand (in MW) and annual energy consumption (in GWh) associated with hydrogen vehicle adoption are reflected in the 2-Medium and 3-High load projections. Hydrogen ZEVs are modelled as less efficient EVs – to estimate the impact on electric load, a simple ratio was applied: over its full fuel lifecycle, a hydrogen fuel cell vehicle was assumed to require 2.1 times more electricity than an EV.[15,16]

[15] https://theconversation.com/hydrogen-cars-wont-overtake-electric-vehicles-because-theyre-hampered-by-the-laws-of-science-139899

[16] EVs typically have higher EERs than hydrogen vehicles. This ratio partially incorporates that assumption along with other fuel life cycle considerations.

The annual electricity consumption for ZEVs is summarized in Table A5.3 below.

Vehicle Type	KMs PER YEAR	Total kWh per Year (EV)	Total kWh per year (Hydrogen Fuel Cell)
Passenger Cars	15,000	3,225	N/A
Light Trucks	15,000	4,473	N/A
Medium Duty Trucks	14,259	7,812	16,405
Heavy Duty Trucks	88,615	135,612	284,785
Buses	55,000	78,160	N/A

Table A5.3 - Annual Electricity Use by Vehicle Type

A summary of the ZEV Sales as a percentage of total sales used for each projection are shown in the Figures A5.8, A5.9 and A5.10. When combined, these assumptions result in the cumulative electricity consumption per projection as shown Figure A5.11 and the peak demand impact as shown in Figure A5.12.

Figure A5.8 - ZEV Sales % by Vehicle Type – 1-Baseline load projection

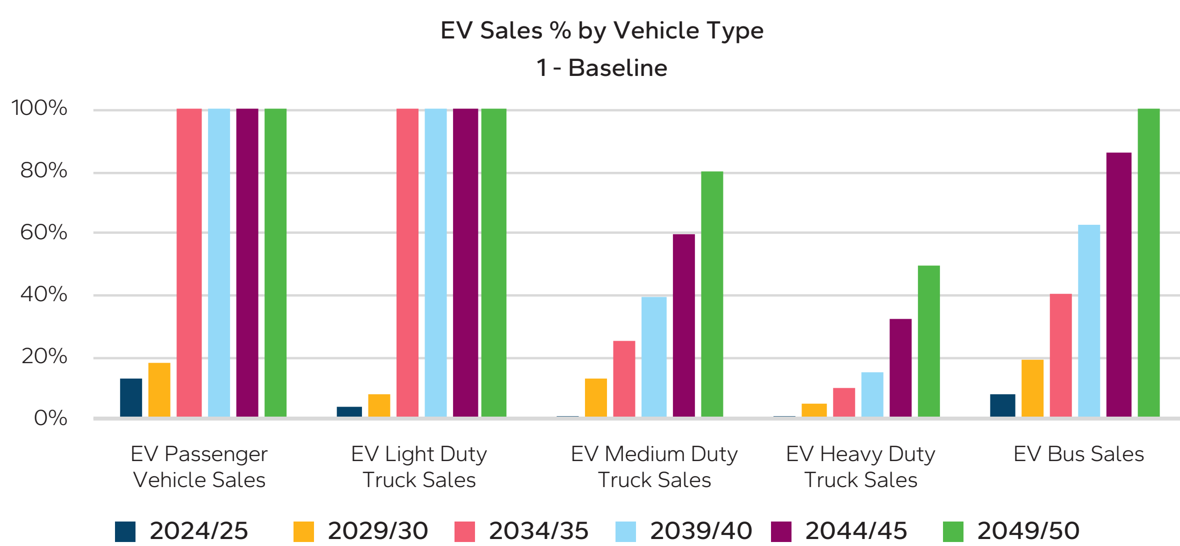


Figure A5.9 - ZEV Sales % by Vehicle Type – 2-Medium load projection

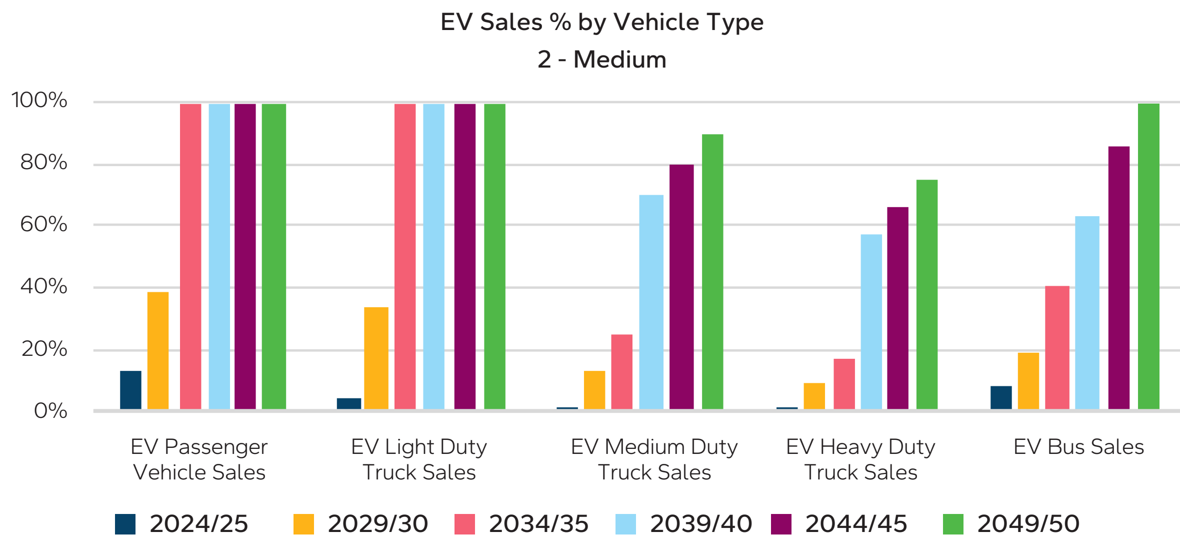


Figure A5.10 - ZEV Sales % by Vehicle Type – 3-High load projection

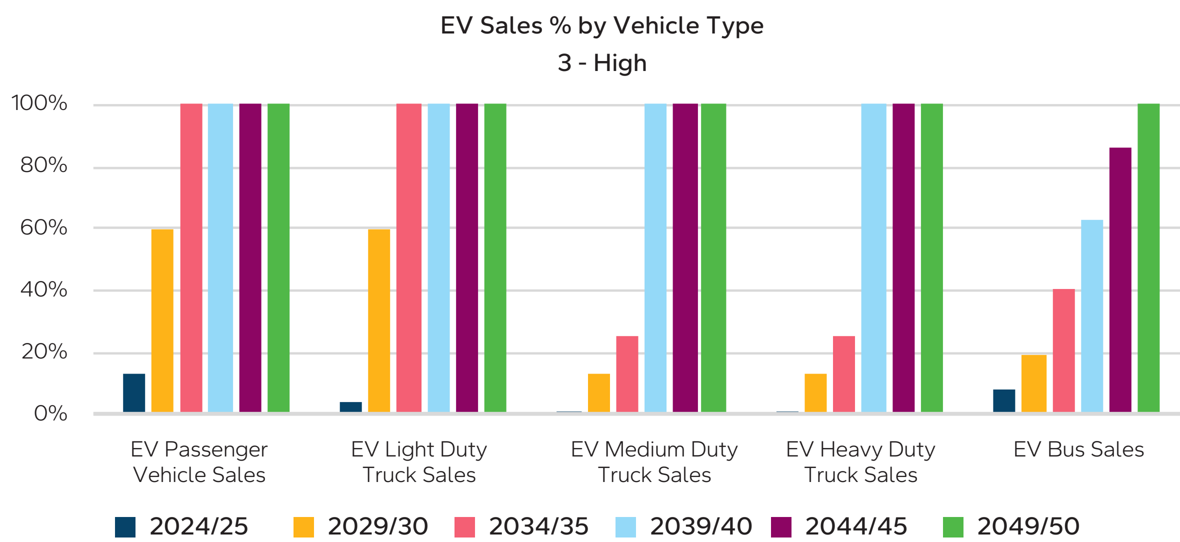


Figure A5.11 - ZEV Electricity Consumption (annual energy in GWh) by Load Projection

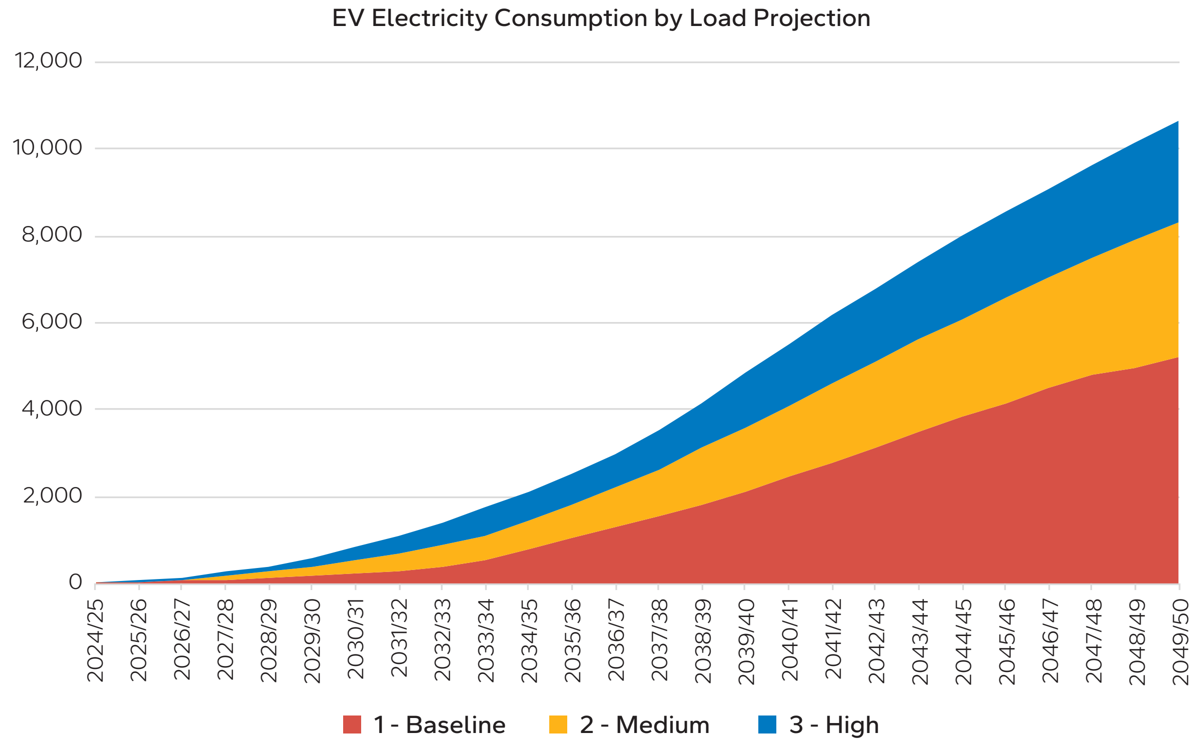
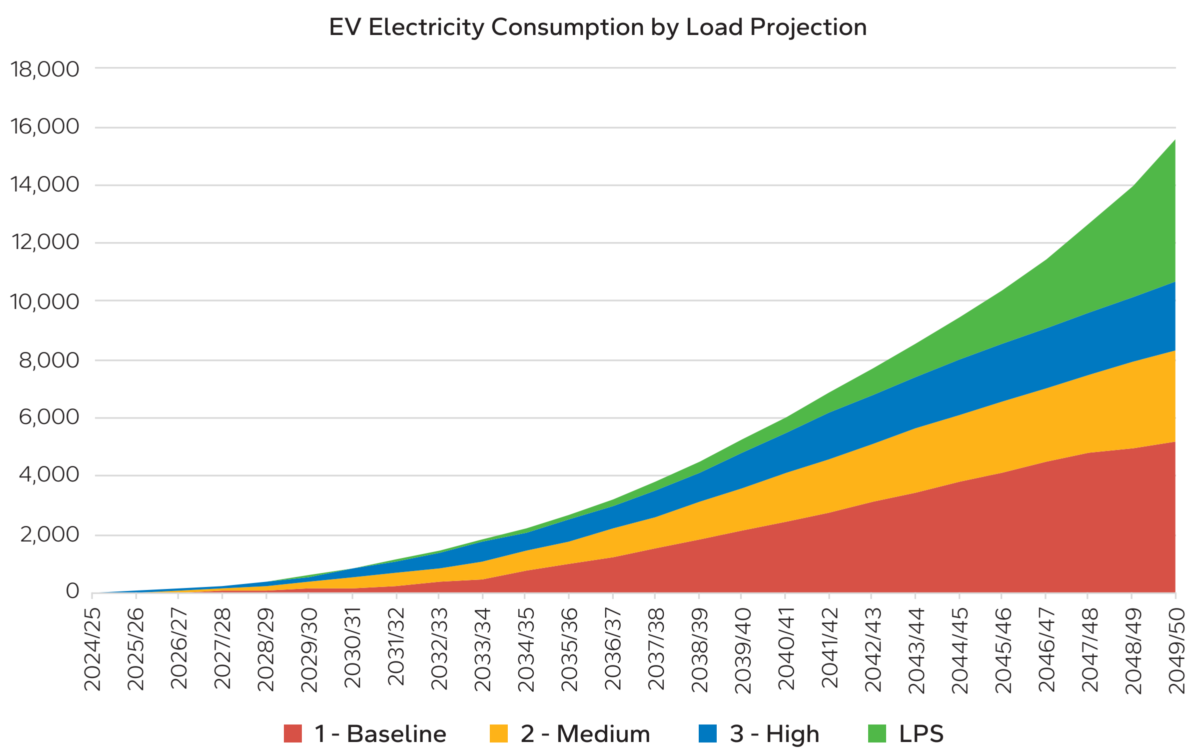


Figure A5.12 - ZEV Peak Capacity by Load Projection



5.3.1. Biofuels in Transportation

Incremental ethanol produced in Manitoba (beyond what is already produced today) was assumed to be fully allocated to the transportation sector as an E85 (85% ethanol, 15% gasoline by volume) blended fuel. While Manitoba Hydro assumed that ethanol was used to displace fossil gasoline consumption in Manitoba, it was not assumed that E100 (100% ethanol fuel) displaced fossil gasoline. As well, Manitoba Hydro did not assume that flex-fuel internal combustion engine vehicles would be able to safely operate on E100 fuel in 2050.[17] Fossil gasoline displacement analysis was performed on an energy basis, as E85 has a significantly different energy density (energy in joules per unit volume of fuel) than fossil gasoline. With an E85 blend, regardless of ethanol volumes produced in Manitoba, 15% of the fuel by volume is still fossil gasoline. The additional electrical energy required to produce this biofuel used in transportation was captured in both the 2-Medium and 3-High load projections.

5.3.2. Net-Zero Residential Transportation Energy Comparison

The electricity and energy requirements of ZEVs depend on their energy efficiency ratio (EER), which accounts for the change in vehicle energy efficiency when substituting one fuel (e.g., electricity) for another (e.g., gasoline). For EVs, the EER typically ranges between 2 and 5,[18] which means less energy is required to drive 1 km in an EV compared to an internal combustion engine vehicle.[19] Hydrogen vehicles tend to have lower EERs, with the federal government assuming 2.4 for light duty vehicles.[20] Lower EERs are already partially considered in the simple 2.1 ratio Manitoba Hydro used to compared hydrogen vehicles to EVs,[21,22] and there is uncertainty in that ratio, therefore two hydrogen vehicle options are presented on Table A5.4 to provide a range for comparison.

Table A5.4 shows energy values for 290,000 passenger vehicles – the number that, if all powered by internal combustion engine vehicles, would emit approximately one million tonnes of CO_2e. It was assumed that any option that includes the combustion of fossil fuels (e.g., internal combustion engine options) must offset those GHG emissions with negative GHG emissions load. Currently, light-duty gasoline and diesel vehicles in Manitoba (including light trucks and SUVs) emit roughly three million tonnes of CO_2e (see Appendix 3 – existing System for more details on GHG emissions in Manitoba).

[17] A flex-fuel internal combustion engine is designed to operate on gasoline and any blend of gasoline and ethanol as per the manufacturer's specifications.

[18] https://data-donnees.az.ec.gc.ca/data/regulatee/climateoutreach/carbon-intensity-calculations-for-the-clean-fuel-regulations?lang=en

[19] https://www.naviusresearch.com/wp-content/uploads/2018/11/BC-EER-Review-Final-Report-2018-11-06.pdf

[20] https://theconversation.com/hydrogen-cars-wont-overtake-electric-vehicles-because-theyre-hampered-by-the-laws-of-science-139899

[21] A fuel cell conversion loss is included.

[22] https://theconversation.com/hydrogen-cars-wont-overtake-electric-vehicles-because-theyre-hampered-by-the-laws-of-science-139899

Table A5.4 - Energy and Electricity Requirements (at Load) [23]

290,000 Passenger Vehicles

Net-Zero Light Duty	Total Average Annual Energy (GWh)	Average Annual Electric Energy (GWh)	Approximate Peak Demand (MW)
Internal Combustion Engine Vehicle + Negative GHG Emissions Load	5,750	1,940	40
Electric Vehicle (EER = 4.1[24])	930	930	120
Hydrogen Fuel Cell Vehicle (EER = 4.1[25])	1,950	1,950	250
Hydrogen Fuel Cell Vehicle (EER = 2.4[26])	3,330	3,330	420

The information in Table A5.4 illustrates that in a net-zero economy:

- EVs will have both lower annual electric energy and total energy requirements than internal combustion engine vehicles, assuming negative GHG emissions technology is used to achieve net-zero.
- EVs have a higher impact on peak demand than internal combustion engine vehicles; however, the impact is substantially less than heat pumps, illustrating how the electrification of transportation has a much lower impact on peak demand than the electrification of heating.
- Hydrogen vehicles have higher electricity requirements (both annual energy and peak demand impacts capacity) than internal combustion engine vehicles, but lower total energy requirements.
- Due to lower EERs, and efficiency losses within the **hydrogen supply chain, hydrogen vehicles typically require 2 to 5 times[27] the energy of EVs (over their full lifecycle)**. This is why Manitoba Hydro assumed hydrogen vehicles would be used more sparingly than EVs.

[23] The values in this table represent the estimated coincident peak impacts at the end-user; they do not include planning reserve margin or transmission and distribution loss implications. The amount of accredited capacity required to serve this load would be higher.

[24] The Clean Fuel Regulation's assumption for light- and medium-duty EV. https://data-donnees.az.ec.gc.ca/data/regulatee/climateoutreach/carbon-intensity-calculations-for-the-clean-fuel-regulations?lang=en

[25] The EV EER assumption is presented, for hydrogen fuel cell vehicles, for comparison purposes; it assumes that the 2.1 ratio sufficiently captures the lower EERs of hydrogen fuel cell vehicles, compared to EVs.

[26] The Clean Fuel Regulation's assumption for light- and medium-duty hydrogen fuel cell vehicles. https://data-donnees.az.ec.gc.ca/data/regulatee/climateoutreach/carbon-intensity-calculations-for-the-clean-fuel-regulations?lang=en

[27] For the 2025 IRP Manitoba Hydro assumed a simple 2.1; however, Manitoba Hydro acknowledges that this may be an optimistic assumption. As EVs were the primary ZEV assumed, this assumption has a minimal overall impact on the 2-Medium and 3-High load projections.

5.4. Space Heating

5.4.1. Space Heating Systems

Space heating fuel choice used within each load projection leads to different levels of electric and natural gas consumption. The space heating systems included within the IRP analysis are:

- All Electric
- Dual Electric - air source heat pump (ASHP) or cold climate ASHP (ccASHP) with electric resistance backup
- Ground Source Heat Pumps (GSHP)
- Dual-Fuel - ASHP or ccASHP with natural gas backup
- Natural Gas
- Other

All electric space heating systems include those powered by electricity such as electric central forced air (CFA) furnace, electric baseboard, and electric boiler. Electric furnaces or baseboard heaters use electric resistance heating elements to generate heat. As long as the electric heating system is located within the home, almost 100% of the electricity consumed by the heating system contributes to heating the house.

A dual electric system consists of either an air source heat pump (ASHP) or a cold climate air source heat pump (ccASHP) with an electric CFA furnace. The ASHP is used for both heating and cooling at outdoor temperatures above -10°C and switches to the electric CFA furnace below -10°C. The ccASHP reacts the same way, however, switches over at -20°C instead of -10°C. Manufacturer performance information for a range of operating temperatures was used in combination with additional considerations which affect performance such as defrost cycles. Manitoba Hydro uses a seasonal coefficient of performance (SCOP) of 1.72 for ASHP and 1.76 for ccASHP which was determined using weather information for Manitoba with the changeover temperatures of -10°C and -20°C respectively.

Ground source heat pumps (GSHP), sometimes referred to as geothermal, are used for both heating and cooling across all outdoor temperatures. For the 2025 IRP, Manitoba Hydro assumes that both the annual heating energy and the peak demand will be reduced by an average factor of 2.0 (i.e., by 50%) for GSHPs compared to electric resistance heating.

A Note on Ground Source Heat Pump Efficiency

Theoretical SCOP and what is realized in use are different values. While Manitoba Hydro assumed a SCOP of 2.0, theoretical SCOP of GSHPs tend to be much higher with some sources indicating that GSHP SCOP values of 4.0 can be achieved in Manitoba. However, Manitoba Hydro's monitoring of GSHP systems and its evaluations of customer experience with GSHP heating systems indicate that heating energy is typically reduced by a factor of about two as compared to electric resistance heating, which a SCOP of 2.0 would imply.

Manitoba Hydro has been collecting information related to GSHPs since the early 2000s. A report published by Phillips, B and Stanski, D. in 2003 highlighted raw coefficients of performance ("COP") ranging from 1.4 to 2.7.[28]

A study was released by Manitoba Hydro in June 2009 on a monitoring project co-funded by Manitoba Hydro and the Canadian GeoExchange Coalition (CGC) through a three-year contribution agreement with Natural Resources Canada (2003-2006).[29] It concluded that "Test data for ten Manitoba homes shows that the SCOP of the monitored ground source heat pump systems range from 1.8 to 3.5 with an average of 2.8 for a one-year period." The report surmised that these results might over-estimate the long-term experience of average customers: "The ten homes monitored are a biased sample since most of the homes were volunteered for the project by experienced and established GSHP contractors and /or distributors that were contacted and nine of the systems were relatively new (less than three years old)." The study also expressed concern about the long-term performance of the systems because of thermal "imbalance to the ground of approximately 5 to1 for heat being extracted from the ground versus heat that is being rejected to the ground".

Another study conducted by the National Renewable Energy Laboratory in Alaska, published in June 2023, showed that the COP averaged 2.68 ranging from below 2.5 in winter to above 3.0 in summer.[30]

[28] Phillips, B., & Stanski, D. (2003, October 21). Residential ground source heat pumps on urban lots: Performance and cost effectiveness. UNIES Ltd. Prepared for North End Housing Project, Inc., Manitoba Housing and Renewal Corporation, Manitoba Conservation (Sustainable Development Innovations Fund), Manitoba Hydro Manitoba R-2000 Home Program, Winnipeg Housing and Homelessness Initiative.

[29] https://www.pubmanitoba.ca/exhibits/mh-gra-2012-13-14/appendix_38.pdf

[30] https://research-hub.nrel.gov/en/publications/performance-evaluation-and-costs-of-a-combined-ground-source-heat

While such studies of individual GSHP heating systems are informative, it is the average long-term experience of customers which determines the net impact of GSHPs on the Manitoba Hydro grid for both energy and peak demand. Customer energy bills provide general household energy usage and provide a macro view of the actual reductions in heating energy from GSHPs achieved by customers where energy consumption before and after the installation of the GSHP can be analyzed. Of the homes analyzed, Manitoba Hydro customers who transitioned from electric resistance heating to a GSHP typically reduced their space heating energy by a factor of 2.0 +/- 0.5 or ranging from 1.5 to 2.5. It is important to note that this ratio is affected not just by the performance of only the GSHP system (i.e. SCOP), but the calculated savings in space heating energy are also subject to uncontrolled factors such as:

- Limited bi-monthly billing information
- Quality of the design and installation of the GSHP
- Maintenance practices of the space conditioning system
- Thermal imbalance of closed loop systems over time
- Changes in occupancy
- Changes in the building envelope (improvements, degradations)
- Changes in thermal comfort expectations
- Changes related to other end uses (adding/removing appliances)
- Customer use, and understanding, of the systems

Thus, Manitoba Hydro's modelling the adoption of GSHPs assumes that space heating energy being reduced by a factor of 2.0 (i.e., by 50%) compared to electric resistance heating will be an accurate representation of the average energy savings considering both GSHP performance and a host of other factors including customer behaviour and maintenance practices. For a customer whose heating and non-heating energy consumption are about the same, converting from electric resistance heating to a GSHP, a 2.0+/-0.5 reduction in their heating consumption would reduce their overall electrical consumption by 17% to 30%.

Customer bills provide insight into seasonal savings in heating energy but do not provide insight into the "peak load reduction" that can be achieved. The "peak load reduction" may be less than the average savings in heating energy if auxiliary electric heating is required at the time of peak load. Manitoba Hydro has developed a space heating load shape for space heating systems and the results indicate that peak energy savings are slightly less than average energy savings.

Dual-fuel systems use an ASHP or a ccASHP paired with a high efficiency natural gas furnace. Similar to the dual electric system, the ASHP provides both heating and cooling at outdoor temperatures above -10°C then switches to a high efficiency natural gas furnace below -10°C. A ccASHP reacts the same way, only at -20°C. A SCOP of 1.72 was used for the ASHP and a SCOP of 1.76 was used for the ccASHP. Natural gas furnace efficiencies are discussed in the following paragraph.

Natural gas heating systems are rated by their annual fuel efficiency (AFUE), which describes how efficient a heating system is over the entire heating season. High efficiency natural gas furnaces are the primary system moving forward and have AFUE ratings of 92% and above. Mid efficiency furnaces have an AFUE rating between 78% - 84% but have not been available for sale since 2009. Standard or conventional furnaces have an estimated AFUE rating of 60% and have not been available for sale since 1995. Gas boilers (high efficiency/mid efficiency/conventional) also use natural gas for space heating.

Other space heating systems include wood stove, fuel oil furnace, diesel furnace, propane furnace, and shared heat (heating not included on bill and often captured via a common service for a building). Other space heating systems make up 1.7% of total residential heating systems and shared systems make up 7.6% according to the 2023 Residential Energy Use Survey.

The relative mix of primary space heating technologies in future scenarios depends upon assumptions about the performance of the technologies and views about net-zero economy 2050 pathways. For example, Dunsky Energy + Climate Advisors' 2023 "An Electricity Roadmap for Manitoba" report envisioned geothermal heating as "the ideal heating source for Manitoba's cold winters". However, the Canadian Climate Institute (CCI) cost-optimal path to a net-zero economy in Manitoba had home heating in "2050 Heat Exchange" being 72% (i.e., ASHP, ccASHP, GSHP), 21% electric baseboards and 6% hybrid heating (i.e., electric heat pump with gas backup) and commercial and industrial spaces being 10% heat pumps, 19% all-electric (i.e. electric baseboards, furnaces, and boilers) and 50% hybrid heating.[31] The CCI did not foresee a role for GSHP systems.[32] This IRP assumes an intermediate role for GSHP as indicated in Figure A5.13.

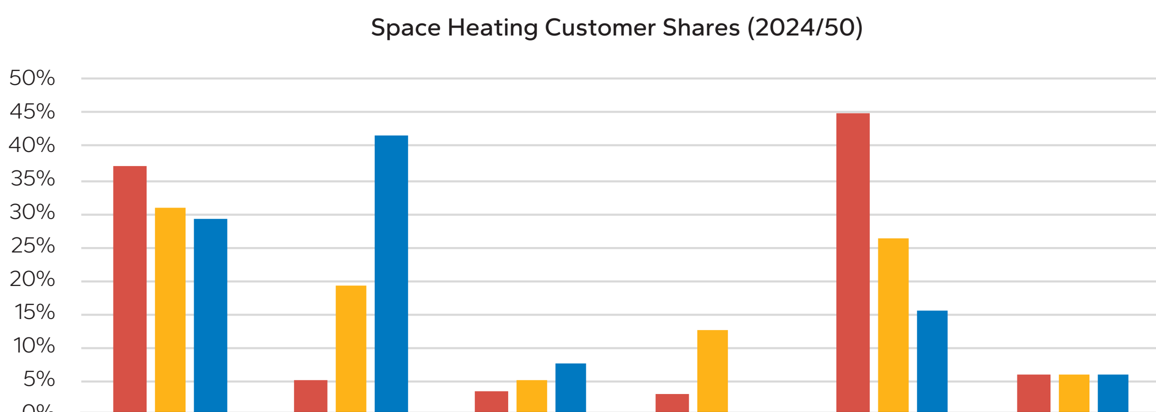
[31] https://climateinstitute.ca/wp-content/uploads/2024/06/Heat-Exchange-Report-Canadian-Climate-Institute.pdf

[32] Confirmed through communications with CCI

Space heating assumptions were developed for new and existing customers in the residential and commercial sectors. The following describes how the space heating systems described above are applied for each scenario:

- **1-Baseline load projection** assumes minimal changes from current policies and customer decisions and slow adoption dual-fuel systems are introduced.
- **2-Medium load projection** includes dual-fuel space heating systems. A combination of policy, incentives, and rates has led to new system installations that were previously assumed to be natural gas fueled to shift toward dual-fuel systems. This includes increased adoption of dual-fuel cold climate air source heat pumps (ccASHP), as well as dual electric heating ccASHP systems, rather than traditional air source heat pumps (ASHP) and ground source heat pumps (GSHP). The result is the same number of total space heating system installations but a reduction in natural gas consumption as compared to not including dual-fuel systems in this projection.
- **3-High load projection** assumes no dual-fuel systems. In this load projection, it is assumed that as air conditioning (A/C) units reach their end of life, they are replaced with dual electric heating and GSHPs. Dual electric ccASHPs are the primary option followed by GSHPs. New installations also start to see a shift to dual electric heating system.

Figure A5.13 shows the percentage of customers by space heating system type for each load projection.



	All Electric	Dual Electric System	Geothermal	Dual Fuel System	Natural Gas	Other
1-Baseline Load Projection	37%	5%	4%	3%	45%	6%
2-Medium Load Projection	31%	19%	5%	12%	26%	6%
3-High Load Projection	29%	42%	8%	0%	16%	6%

Figure A5.13 - Heating System Breakdown by Load Projection

5.4.2. Net-Zero Residential Heating Energy Comparison

Table A5.5 compares the energy requirements of various residential heating options that could be used in a net-zero economy future by the year 2050. For any heating system that includes the combustion of fossil fuels (e.g., natural gas furnaces) the resulting GHG emissions must be offset. It was assumed these offsets are achieved through negative GHG emissions, which in turn add additional electric load to the system.

Terms used in Table A5.5:

- **"Total Average Annual Energy (kWh)"** includes all energy consumed in furnaces and heat pumps, as well as the energy required to achieve negative GHG emissions. The unit ekWh (equivalent kilowatt-hours) accounts for both electrical and non-electrical sources of energy. In the case of hydrogen, the electric energy to produce the hydrogen (via electrolysis) is included instead of the energy consumed in the furnace (hydrogen heating is modelled as a less efficient form of electric heating).
- **"Average Annual Electrical Energy (kWh)"** only includes the electricity consumed in furnaces and heat pumps, as well as the electricity required to achieve negative GHG emissions. It represents the amount of dependable energy required from the electricity system. It does not include the natural gas energy consumed in any furnaces. It does include the electrical energy required to produce hydrogen for hydrogen heating (hydrogen heating is modelled as a less efficient form of electric heating).
- **"Annual Peak Electrical Demand (kW)"** represents the approximate impact of the heating option on Manitoba's peak electrical demand.
- **"Hydrogen Heating"** is the theoretical heating of a home on pure hydrogen, which would be produced in Manitoba by electrolysis. It is included for comparison purposes and was not an option included in any of the load projections.

Table A5.5 - Heating Energy and Electricity Requirements (at load) for a Residential Single Detached Home with Net-Zero GHG Emissions Heating

Net-Zero GHG Emissions Home Heating Option	Total Average Annual Energy (in ekWh)	Average Annual Electrical Energy (in kWh)	Annual Peak Electrical Demand (in kW)[33]
High Efficiency NG Furnace + Negative GHG Emissions Load	25,880	6,210	<0.1
High Efficiency NG Furnace + ASHP (Dual Fuel) + Negative GHG Emissions Load	19,200	7,630	<0.1
High Efficiency NG Furnace + ccASHP (Dual Fuel) + Negative GHG Emissions Load	14,400	8,450	<0.1
Ground Source Heat Pump (GSHP)	8,300	8,300	3.7
Electric Furnace	16,600	16,600	6.4
Electric Furnace + ASHP (Dual-Electric)	13,740	13,740	6.4
Electric Furnace + ccASHP (Dual-Electric)	11,590	11,590	6.4
Hydrogen Heating[34]	26,600	26,600	10.3[35]

Table A5.5 demonstrates that:

- While residential heating options using natural gas furnaces have higher total energy requirements in a net-zero future, due to the need to offset GHG emissions, their electric energy use is comparable to homes with GSHPs, lower than those with ASHPs, and their peak electric load is nearly zero. As a result, dual-fuel systems were more aggressively pursued in 2-Medium load projection to help manage overall peak demand.
- ASHPs and ccASHPs can reduce a home's electric energy use but do not lower peak demand requirements on their own, as they operate equivalent to an electric heating system in cold weather, which is Manitoba's peak demand.

[33] The values in this table represent the estimated coincident peak impacts at the end-user; they do not include planning reserve margin or transmission and distribution loss implications. The amount of accredited capacity required to serve this load would be higher.

[34] For this comparison, for simplicity, Manitoba Hydro assumed 1.6, based on the same ratio used for hydrogen transportation, but without assumed losses at the vehicle and with an assumed 10% loss at the natural gas/hydrogen furnace.

[35] Note: This assumes only modest hydrogen storage exists in Manitoba. The installation of large scale hydrogen storage could potentially mitigate the impact on accredited capacity requirements. Limiting the production and use of hydrogen in winter months could also mitigate the impact on annual peak demand.

A Note on Hydrogen Based Heating

Hydrogen based heating — including both blending hydrogen with natural gas and 100% hydrogen systems — is more energy- and electricity-intensive than all the other net-zero heating options analyzed. The greater the hydrogen content in a blended system, the more energy-intensive the option becomes. Therefore, for the 2025 IRP, Manitoba Hydro assumed hydrogen would not be blended into the provincial natural gas distribution system in the future, as reducing GHG emissions through negative GHG emissions or electrification of space heating is more energy-efficient than displacing natural gas with hydrogen.

Table A5.6 is a scaled-up version of Table A5.5. Instead of showing energy values for a single home, it shows totals for 313,000 single detached homes — the number of homes that, if heated exclusively with high-efficiency natural gas furnaces, would directly emit one million gross tonnes of CO_2e in an average weather year in Manitoba. Currently, residential home heating in Manitoba emits about 1.2 million tonnes of CO_2e (see Appendix 3 – Existing System for more details on GHG emissions in Manitoba).

Table A5.6 - Energy and Electricity Requirements (at load)[36] for 313,000 Residential Single Detached Homes with Net-Zero GHG Emissions Heating

Net-Zero GHG Emissions Residential Heating Option	Total Average Annual Energy (in eGWh)	Average Annual Electrical Energy (in GWh)	Approximate Annual Peak Demand (in MW)
High Efficiency NG Furnace + Negative GHG Emissions Load	8,100	1,900	40
High Efficiency NG Furnace + ASHP (Dual Fuel) + Negative GHG Emissions Load	6,000	2,400	24
High Efficiency NG Furnace + ccASHP (Dual Fuel) + Negative GHG Emissions Load	4,500	2,600	12
Ground Source Heat Pump (GSHP)	2,600	2,600	1,160
Electric Furnace	5,200	5,200	2,000
Electric Furnace + ASHP (Dual-Electric)	4,300	4,300	2,000
Electric Furnace + ccASHP (Dual-Electric)	11,590	11,590	6.4
Electric Furnace + ccASHP (Dual-Electric)	3,600	3,600	2,000
Hydrogen Heating	10,900	10,900	4,200

[36] The values in this table represent the estimated coincident peak impacts at the end-user; they do not include planning reserve margin or transmission and distribution loss implications. The amount of accredited capacity required to serve this load would be higher.

Comparing energy impacts of electrification of transportation versus space heating

As demonstrated in Table A5.5 and Table A5.6, the electrification of heating has the potential to result in substantial impacts on peak electric load, even when heat pumps are incorporated. Comparably, the electrification of transportation has a much lower impact on peak demand than the electrification of space heating as show in Table 5.4.

Reducing provincial GHG emissions by 1 million tonnes of CO_2e annually through electrification of residential space heating increases annual peak electricity demand by approximately 1,160 to 2,000 MW, whereas the same GHG reduction through electrification of light-duty vehicles increases annual peak electricity demand by approximately 120 MW. On a per-tonne CO_2e reduced basis, in Manitoba, electrifying residential space heating increases annual peak demand by 10 to 17 times more than electrifying residential transportation.

5.5. Customer Self-Generation and Storage

Customer self-generation can include multiple types of electrical energy systems. Examples of customer self-generation include solar photovoltaic (PV), small wind turbines, fossil-fuel or biomass generators, on-site energy storage systems, and microgrids. These systems generate electricity for customers' use and when customer demand is less than the electricity produced, the electricity is sent to the grid. The 2025 IRP uses solar PV technology to represent future customer self-generation and varying rates of solar PV adoption are applied to different load projections.

To determine the load projection impacts, the 2025 IRP uses a Bass diffusion model to estimate how solar PV is adopted throughout the study period.[37] The 2025 IRP assumes an average solar PV installation size of 10 kW for residential customers where each system generates 11,680 kWh per year. The 2025 IRP assumes an average solar PV installation size of 90 kW for commercial / industrial / agricultural customers where each system generates 105,120 kWh per year. Based on information collected from the Solar PV Generation Performance Load Research study,[38] it is assumed that 60% of the electricity generated by solar PV installations is sold back to the grid. Customer self-generation impacts are determined across an hourly (8760 hours per year) load profile. Table A5.7 shows the total installed capacity and annual electrical energy produced by solar PV installations at the end of the study period.

[37] The Bass diffusion model is a mathematical framework used to forecast how a new product or technology is adopted over time within a population

[38] https://www.hydro.mb.ca/your_home/pdf/solar_pv_generation_performance_load_research_study.pdf

Table A5.7 - Solar PV Installations in 2049/50 by Load Projection

	1 - Baseline Load Projection	2 - Medium / 3 - High Load Projection
Number of Installations	8,100	1,900
Total Installed Capacity (MW)	6,000	2,400
Annual Electrical Energy (GWh)	4,500	2,600
Total Consumed by Customer (GWh)	2,600	2,600
Total Sold Back to Grid (GWh)	5,200	5,200

5.6. Energy Efficiency

Each load projection includes a base level of energy efficiency. In 2024, Efficiency Manitoba, in collaboration with Manitoba Hydro, prepared a longer-term extrapolation of future energy efficiency savings adhering to the mandated minimum average annual targets as outlined in the Efficiency Manitoba Act. Energy efficiency savings are provided for both program-based energy efficiency initiatives and the savings due to codes and standards assumed to reduce electricity and natural gas forecasts in all cases. The base energy efficiency cumulative savings for electrical energy, electrical demand, and natural gas are shown in Figure A5.14 through Figure A5.16.

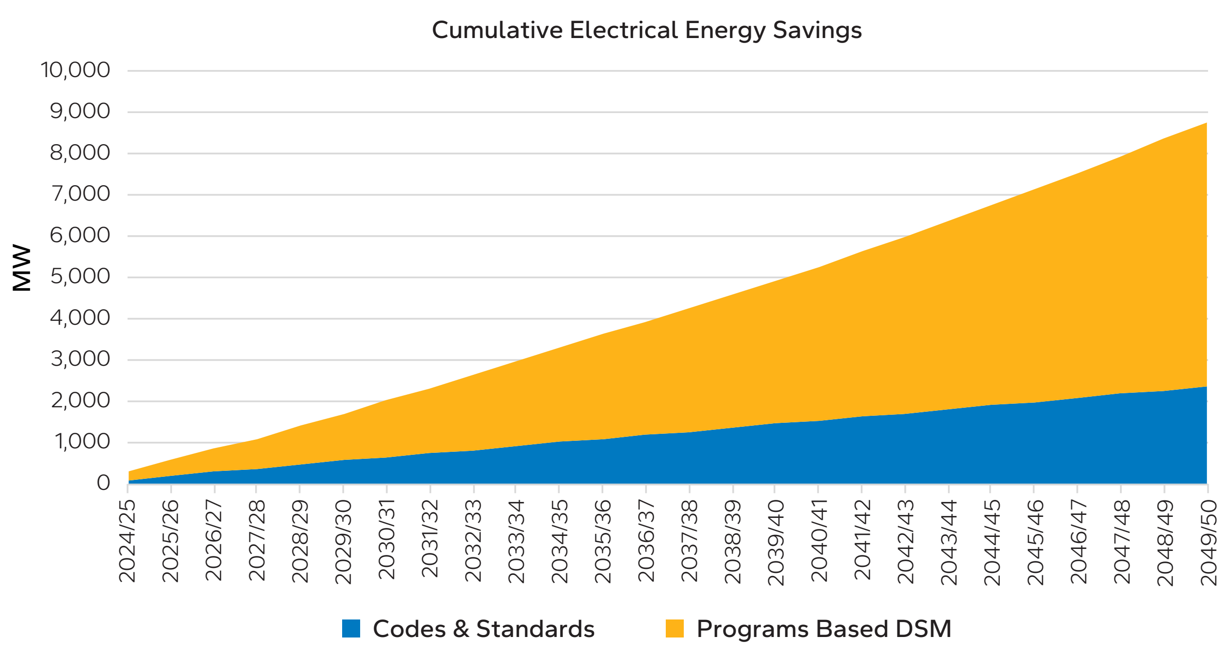


Figure A5.14 - Base Energy Efficiency - Electrical Energy

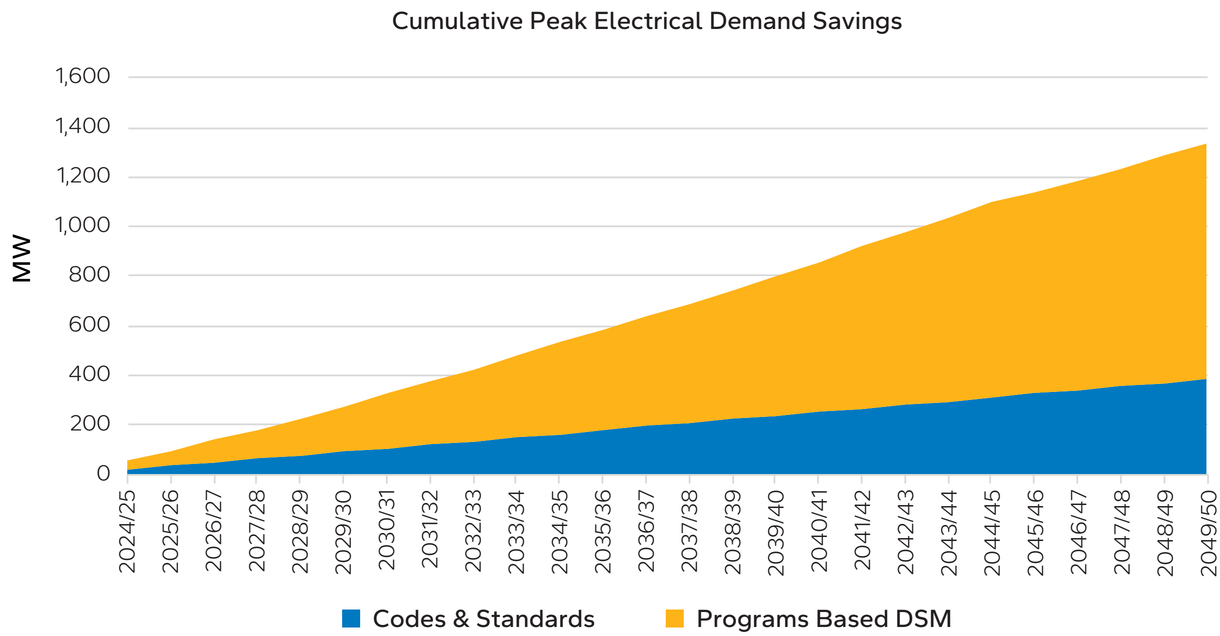


Figure A5.15 - Base Energy Efficiency - Electrical Demand

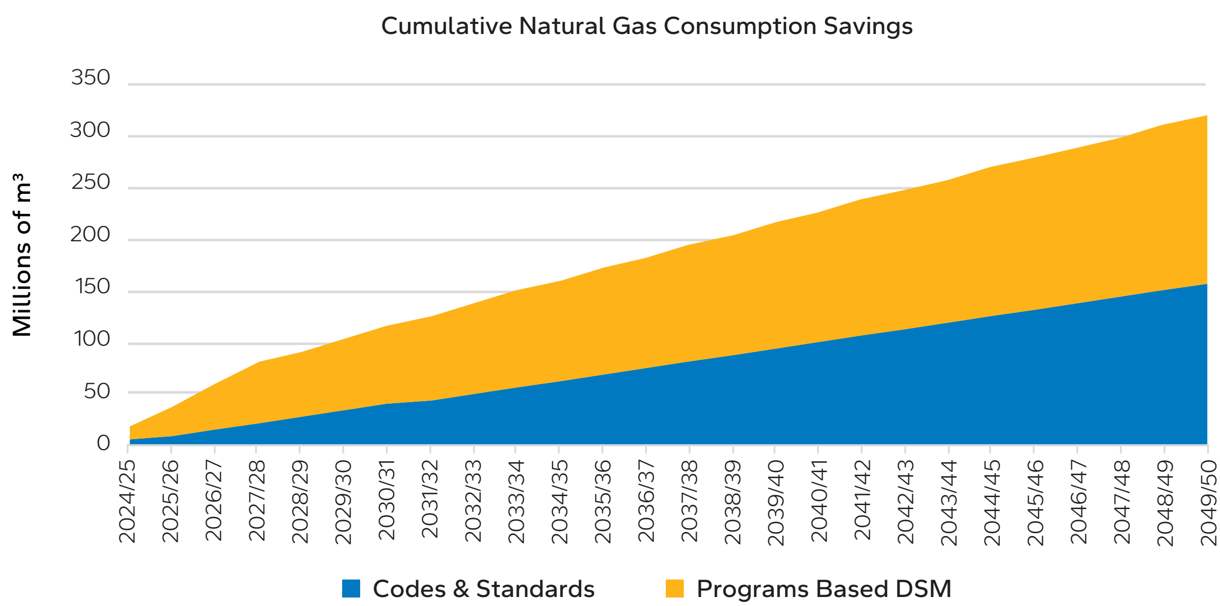


Figure A5.16 - Base Energy Efficiency - Natural Gas Volume

The 2025 IRP also considered additional energy efficiency measures as selectable resources. Detailed description of these measures is provided in Appendix 6 - Resource Options.

5.7. Industrial Decarbonization and Economic Development

A proxy value was used based on the theme of each load projection to account for several interacting energy drivers, including:

- Industrial decarbonizing via electrification of some existing industrial processes (e.g. electric boilers).
- Economic development and new industries locating in Manitoba.
- The possible reduction in consumption for existing customers.

In 2-Medium Load Projection, a 50 MW increase for electrification was added every six years starting in 2028/29, and an additional 50 MW from economic development efforts was added every six years starting in 2031/32.

In 3-High Load Projection, both electrification and economic development were represented with escalating increases — 50 MW, 75 MW, 100 MW, 125 MW — added every six years starting in 2028/29 and 2031/32, respectively.

The magnitude and pace of electrification represents approximately one to two industrial customers switching from natural gas to electricity, plus the potential arrival of one large new industrial customer in Manitoba every six years. Figure A5.17 shows the resulting additional electrical energy requirements over the study period.

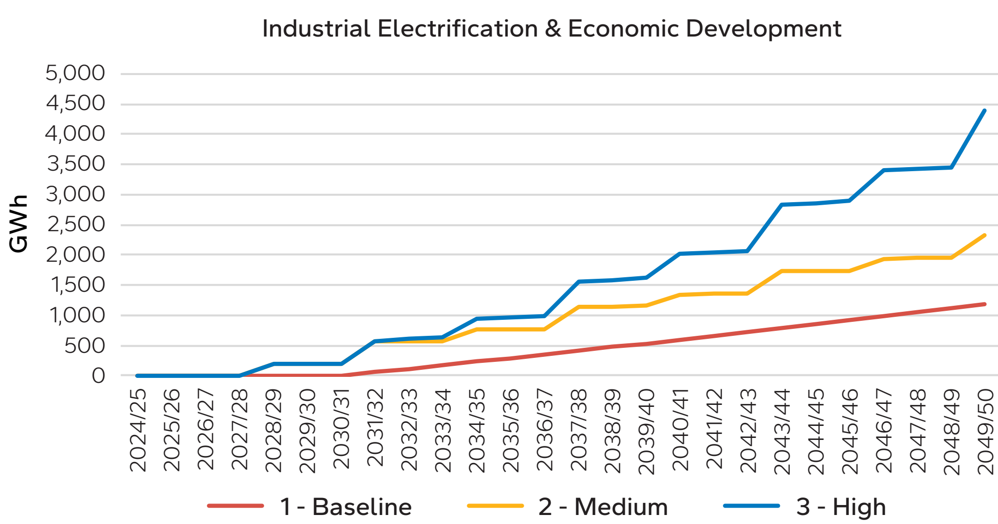


Figure A5.17 - Increase in Electricity consumption due to Industrial Electrification and Economic Development by Load Projection

As previously discussed, the 2025 IRP assumes that some industrial customers in a net-zero economy will use carbon capture and sequestration (CCS), in addition to electrification. Table A5.8 presents the additional annual electrical energy and peak demand impact of industrial CCS, in 2049/50. To both simplify analysis and to isolate the impact of carbon capture, for the 2025 IRP it was assumed CCS loads do not commence until 2049/50; however, it is possible that, under a net-zero economy future, industrial CCS would start ramping up before 2050. With strong industrial GHG pricing some level of CCS may be deployed much sooner.

Table A5.8 - Load Impact of Incremental Industrial CCS in 2049/50

Incremental Industrial CCS	1 - Baseline Load Projection	2 - Medium Load Projection	3 - High Load Projection
Annual Electrical Energy Impact (GWh)	N/A	720	720
Annual Peak Electric Load Impact (MW)[39]	N/A	90	90

Industrial CCS could presumably be reduced during winter months; however, since the energy requirements of CCS are much lower than the assumed negative GHG emissions load, it was assumed that CCS load was not reduced during the winter and would match the hourly load shape of a typical industrial load customer.

[39] This represents the load impact (in MWs) of incremental industrial CCS during the system's coincident peak.

5.8. Demand Response

Demand response is a strategy used to adjust electricity consumption patterns by encouraging customers to reduce or shift their usage during periods of high system demand. The primary goal is to reduce peak demand, which in turn reduces the need for additional system capacity and infrastructure.

In developing each load projection, Manitoba Hydro leveraged the results of a demand response market potential study that was specific to Manitoba Hydro conducted by Dunsky Energy + Climate Advisors. The study helped estimate the potential impacts of implementing demand response programs across the province.

Manitoba's hourly energy profile — which shows when and how much electricity is used throughout the year — reveals that peak demand typically occurs during winter mornings and evenings. Demand response efforts are therefore focused on these periods.

Figure A5.18 illustrates how demand response can reduce electricity consumption during the morning peak and shifting it to midday, when overall demand is lower, to flatten the demand curve.

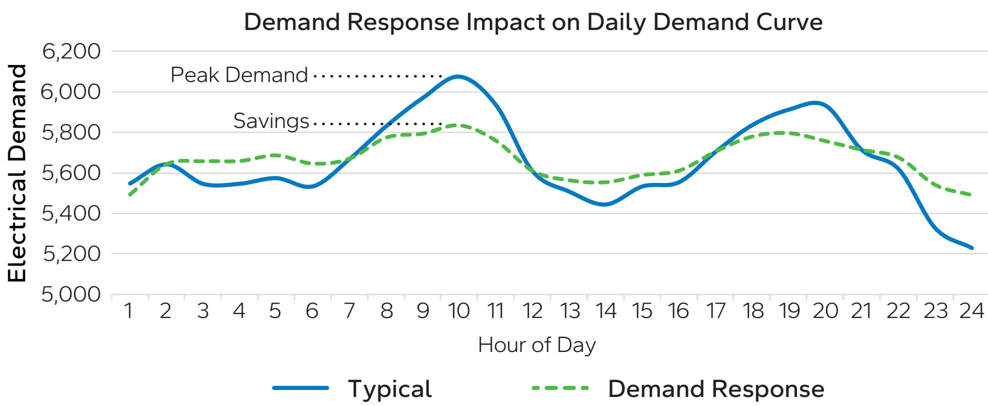


Figure A5.18 Illustration of Demand Response Impact

The demand response assumed within the IRP did not specifically model each potential demand response program offering but grouped the associated impacts in the following categories recognizing that each provide different opportunities and effects in reducing electrical peak loads.

- Demand response with bounce back effect.
- Commercial / Industrial curtailable load (Curtailable Rates Program).
- Electric vehicle smart charging.

Demand response with bounce back effect (e.g. thermostat controllers) recognize that calling a demand response event would reduce energy consumption during the event, but after the event was completed, the customer would use additional energy to return to normal (e.g. following an event where a thermostat was lowered, the customer would use electricity to increase temperature back to the desired temperature). While some energy consumption may be permanently avoided, most of the energy use is simply shifted to a different time period (i.e., load shifting).

Commercial / industrial curtailable load recognizes that when calling an event, customers would reduce their electricity consumption and following the event would return to normal operations without an increase (i.e., bounce back) to make up the energy not used during the event. This is due to most industrial systems typically running at full capacity and not having additional capabilities of pushing beyond their full capacity.

Electric vehicle smart charging was separated recognizing there is a pattern as to when customers can charge their electric vehicles and the time of day of a demand response event may limit the ability to reduce electric vehicle charging during that event.

Demand response programs reduced winter peak demand in the months of December, January, and February by attempting to flatten the demand profile. A simplifying assumption is that the total annual energy requirements would remain unchanged, recognizing that some larger, higher capacity factor loads would likely experience a reduction in energy consumed when the load is curtailed.

For industrial demand response, the existing curtailable rate program (CRP) at 161 MW was extended throughout the study period to represent an enhanced and expanded program with more participants contributing to the overall demand reduction.

There were three demand response optimization load shapes studied and applied in the analysis, which were 2024-2034, 2035-2041, and after 2041 as load shapes changed over these periods. To ensure demand response options were aligned with supply side decisions, the timing of demand response resources was aligned with the first need for new capacity resources in each scenario. The annual impact of the load modification to each of the load projections shown in Figure A5.19.

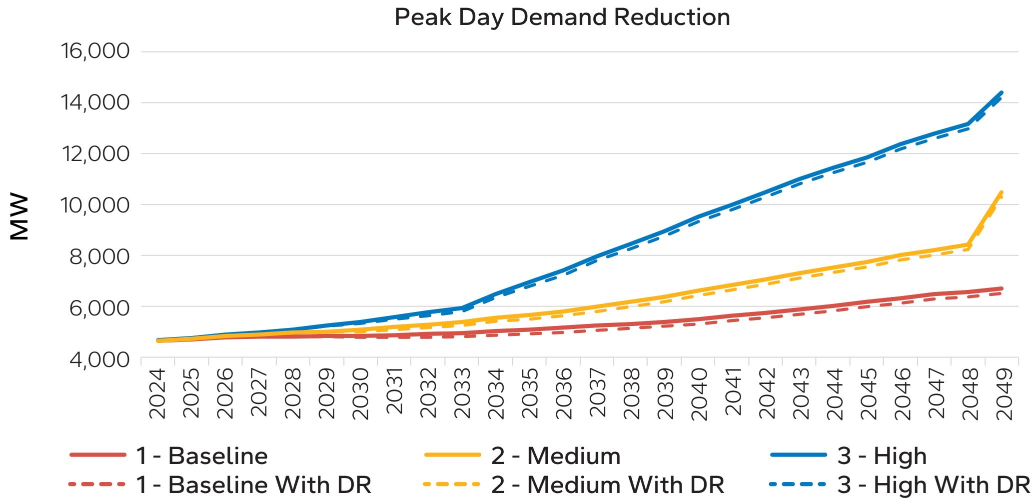


Figure A5.19 - Peak Day Demand Reduction

5.9. Biofuel Production

There are certain energy end-uses where electrification is less practical and it may be useful to continue to use fuels (e.g., heavy-duty transportation, electricity generation in remote communities). For these energy end-uses, a potential option to make continued fuel use compatible with a net-zero economy future in Manitoba is through the use of GHG-neutral biofuels. This section presents Manitoba Hydro's assumptions related to electric loads for biofuels as it aligns with the net-zero economy guiding principles.

5.9.1. Biofuel Production Loads

Table A5.9 presents the 2050 electrical energy and peak load required for additional production from current levels of Manitoba biofuel production in the 2-Medium load projection and 3-High load projection, estimated based on Manitoba Hydro's biofuel assumptions described in the subsequent sub-sections. Biofuel types considered in the analysis include biodiesel, biomethane, solid biomass, and ethanol.

Table A5.9 – 2050 Load Impact of Incremental Biofuel Production

Incremental Biofuel Production	1 - Baseline Load Projection	2 - Medium Load Projection	3 - High Load Projection
Annual Electrical Energy Impact (GWh)	N/A	2,060	2,060
Annual Peak Electrical Demand Impact (MW)[40]	N/A	260	260

[40] This represents the load impact (in MWs) of incremental biofuel production (full fuel life cycle) during the system's coincident peak.

Considering that it will likely take several years for Manitoba's biofuel production industry to grow to the assumed 2050 production levels, it was assumed for the 2-Medium and 3-High load projections that additional biofuel production from current levels would commence in 2030 and increase linearly to 2050 levels which reach the limits described in section 5.9.3.

Manitoba Hydro assumed no reduction in biofuel production during winter months because doing so would require a substantial amount of incremental fuel storage in the province. Biofuel production loads were assumed to impact annual peak electrical demand and follow a typical industrial customer load profile during winter.

5.9.2. Modelled Biofuel Applications

For the 2025 IRP, Manitoba Hydro identified potential uses for the made-in-Manitoba biofuels considered — biodiesel, biomethane, solid biomass, and ethanol — in a net-zero economy for both load forecasting and resource modelling.[41] The analysis completed for allocation of the different biofuels avoided double counting of fuels between electricity generation and other direct combustion applications (e.g., transportation or space heating).

As a modelling simplification, it was assumed that incremental biodiesel, biomethane, and solid biomass were exclusively allocated for potential use in electricity generation applications. Manitoba Hydro did not assume any other combustion GHG emission reductions were achieved, in non-electricity generation sectors, via the use of these three biofuels – even if, in a specific scenario, they were not fully consumed for electrical generation. Discussion of biofuels used in electricity generation is included in Appendix 7.1 – Modelling and Analysis Approach.

Ethanol was fully allocated to the transportation sector applications as an E85 (85% ethanol, 15% gasoline by volume) blended fuel as previously discussed.

[41] No claims or guarantees are made that Manitoba Hydro has identified the best, most efficient, or most economic pathway to allocating these biofuels.

5.9.3. Biofuel Limits

In line with the guiding principles previously discussed, it was assumed that Manitoba was self-reliant for delivering GHG emission reduction solutions within the province to support a net-zero economy in 2050. It was recognized that Manitoba does not have adequate resources to sustainably replace all fossil fuels currently consumed in the province with biofuels. To estimate a technical limit on biofuel production that would not result in a net incremental GHG emissions increase, Manitoba Hydro assumed that:

- There would not be major market disruptions in Manitoba's agricultural sectors to support increased biofuel production.
- Biofuel feedstocks do not compete. While this may under or overestimate certain individual biofuels, this more accurately estimates overall limits for biofuels in the province from a total energy perspective.
- End-use biofuel limits consider, on an energy basis, only biomass sources that would be sustainably replenished and with all upstream greenhouse gas emissions from harvesting, processing, and transportation accounted for.

Table A5.10 below summarizes the incremental limits assumed, above and beyond the current use of biofuels within Manitoba. Manitoba Hydro assumed a Manitoba biofuel limit of 36.9 PJ for the 2025 IRP. For comparison, the most recently available data for fossil fuel use in Manitoba is approximately 221 PJ annually. Manitoba Hydro acknowledges that there are other biofuels beyond what is listed.

Table A5.10 - Manitoba Incremental End-Use Biofuel Limits

Incremental biofuels considered in the net-zero 2050 economy analysis	Upper Limit (mass or volume)	Upper Limit (PJ)
Biodiesel and Sustainable Aviation Fuel	40 million L	1.4
Ethanol	840 million L	17.9
Biomethane	170 million m3	6.7
Solid Biomass (wheat straw)	830 kilotonnes	10.9
Total	-	**36.9**

The values in Table A5.10 represent Manitoba end-use biofuel limits; they are not the gross production limits. Manitoba Hydro assumed that all incremental Manitoba biofuels are produced and transported using a combination of biofuels and electricity. No fossil fuels were assumed to contribute to the additional biofuel lifecycles. This was done to ensure that assumed incremental biofuel production has net-zero GHG emissions and did not require any negative GHG emissions during the GHG emissions balancing process. As a result of this methodology, less biofuel is available to end-users in Manitoba than are produced, as some biofuels are consumed to facilitate the production and transportation of biofuels.

Biofuel availability analysis in support of the 2025 IRP was done to estimate high-level limits on biofuel for electricity system modelling and net-zero analysis purposes and should not be taken as a definitive indication of the overall technical potential of biofuel in Manitoba. Further analysis on biofuel/biomass feedstock availability in Manitoba is required to get a better and more accurate understanding of the technical and economic potential.

5.9.4. Biofuel Production Efficiencies

To estimate the net quantity of incremental biofuels available in the wider economy, Manitoba Hydro performed an energy balance based on the inputs required both on the farm (to yield the assumed feedstock) and at the production facility.

Table A5.11 shows the ratio of energy-out over energy-in for all biofuels considered in the 2025 IRP. Where applicable, ratios are calculated on a lower heating value basis using the gross fuel production and all required energy inputs on an equivalent energy basis. An energy-out over energy-in value above 1.0 indicates a greater delivery of energy than energy consumed to produce that fuel.

Table A5.11 - Production Efficiency of Biofuels Considered

Fuel	Feedstock Assumed	Energy Out / Energy In
Biodiesel (or, alternatively, Sustainable Aviation Fuel)	Oilseed crops	1.4
Ethanol	Corn Stover	2.9
Biomethane	Various	7.2
Solid Biomass	Wheat straw	8.3

While biodiesel is one of the most flexible biofuels, in terms of potential applications it is also one of the most energy intensive to produce. Conversely, solid biomass is one of the least energy intensive to produce but has more technical barriers to its use in the economy (e.g., most vehicles cannot operate on solid biomass).

5.10. Hydrogen Production

Consistent with the net-zero economy guiding principles, Manitoba Hydro assumed that any incremental hydrogen production from current levels for use in the province would be produced locally in Manitoba using electrolysis. It is assumed that the electricity needed for this process would be supplied from Manitoba Hydro's electricity grid. Therefore, the production of incremental hydrogen is assumed to increase annual provincial electrical energy requirements and peak electrical demand regardless of its end use.

Manitoba Hydro did not assume a production limit on hydrogen production for the 2025 IRP, as there is no theoretical functional limit on the quantity of hydrogen that could be produced in Manitoba. The limited use of hydrogen in the load projections is based on its poor energy efficiency ratio, regardless of the fact there is no production limit. The 2025 IRP assumes no export quantities of hydrogen.

Based on these general assumptions, the potential electrical energy required to support hydrogen production in Manitoba is dependent on hydrogen's end-use applications:

- Incremental fuel-cell vehicle applications, as discussed previously.
- For electricity generation (more details are provided in Appendix 6 – Resource Options and Appendix 7.1 - Modelling & Analysis Approach).

As discussed previously, no incremental hydrogen is assumed for space heating.

5.11. Negative GHG Emissions Load

As discussed previously, under the assumptions and guiding principles used in the 2025 IRP, analysis revealed that a net-zero economy by 2050 in Manitoba is not possible without negative GHG emissions. GHG emission reductions alone are insufficient in supporting a net-zero economy by 2050.

For the purposes of the 2025 IRP analysis, Manitoba Hydro included a proxy negative GHG emission load for a load projection to represent a potential net-zero economy future. While negative GHG emissions industries could start to grow in Manitoba at any time, the analysis assumed no negative GHG emissions load until 2049/50. This assumption was made for the following reasons:

- It simplified the analysis.
- It disaggregated the GHG emission reductions assumed before the implementation of negative GHG emissions technology, making it more transparent what GHG reductions were assumed.
- Manitoba Hydro assumed energy-intensive negative GHG emission technologies would be one of the last options pursued to reduce provincial GHG emissions.
- Negative GHG emissions technology is an emerging technology – the earliest in-service date of large scale negative GHG emissions technology is highly uncertain.

5.11.1. Negative GHG Emissions Technology

For the purposes of the 2025 IRP, Manitoba Hydro used electricity powered direct-air carbon capture and sequestration (DACCS) as the default proxy for negative GHG emissions (i.e., carbon dioxide removal or CDR). This aligns with general scientific consensus that GHG removal methods will be necessary if the goal is to limit global warming to 1.5C above pre-industrial levels.[42] Both natural processes and some emerging technologies can remove carbon dioxide from the atmosphere. There is no detailed (non-high level) estimate of the potential for achieving persistent,[43,44] additional,[45] permanent,[46] and sustainable negative GHG emissions from natural processes in Manitoba. Further rationale for this choice is as follows:

- The Canadian Energy Regulator assumed DACCS would be a major contributor of negative GHG emissions[47] in 2050 for its Energy Future 2023 Canada Net-Zero Scenario, with the DACCS industry growing exponentially through 2050[48].
- DACCS is very energy intensive. The choice of DACCS as a proxy represents a conservative, precautionary approach to Manitoba Hydro's planning, intended to protect against coming up short of the electrical energy needed for any future negative GHG emissions solution or further electrification.
- Considering the level of uncertainty surrounding the energy intensity of various negative GHG emissions technologies or processes, planning for the most energy-intensive technology is a reasonable planning assumption.
- Manitoba Hydro has quantified data on the potential energy requirements of DACCS, based on current technology.
- DACCS load can be reduced during the winter months, to minimize the impact on winter peak, without adversely impacting Manitoba's overall economy.

[42] https://www.energy.gov/fecm/carbon-dioxide-removal

[43] https://www.iisd.org/system/files/publications/carbon-dioxide-equivalent-sequestration-agro-manitoba.pdf

[44] Persistence, in this context, refers to sequestration potential persisting over long periods of time. Some natural processes, such as tillage practices, will eventually saturate in their capacity to sequester carbon.

[45] https://ghgprotocol.org/sites/default/files/standards/ghg_project_accounting.pdf

[46] https://gazette.gc.ca/rp-pr/p2/2022/2022-06-08/html/sor-dors111-eng.html

[47] The Canadian Energy Regulator also assumed natural processes and BECCS (including BECCS combined with hydrogen production) would be major contributors of negative GHG emissions in a net-zero economy future. As noted in previous sections, there are limits to BECCS deployment in Manitoba.

[48] https://apps2.cer-rec.gc.ca/energy-future/?page=emissions&mainSelection=greenhouseGasEmission&yearId=2023&sector=&unit=megatonnes&view=&baseYear=2050&compareYear=2050&noCompare=&priceSource=&scenarios=Canada%20Net-zero&provinces=MB&provinceOrder=YT,SK,QC,PE,ON,NU,NT,NS,NL,NB,MB,BC,AB&sources=LAND,ELECTRICITY,HYDROGEN,AIR&-sourceOrder=WASTE,AGRI,BUILD,HEAVY,TRANSPORTATION,FOSSIL,LAND,ELECTRICITY,HYDROGEN,AIR

- DACCS facilities already exist, with dozens of plants commissioned to date worldwide and plans for over a hundred additional large-scale installations at various stages of development.[49]
- DACCS technology can potentially operate 100% on electricity.[50]
- The Global Warming of 1.5°C Special Report from the International Panel on Climate Change notes that "(DACCS) is theoretically only constrained by geological storage".[51] In Manitoba, if enough electricity is available, the theoretical functional limit of DACCS may be quite high as there is substantial potential geological storage available (as detailed in Appendix 6 – Resource Options).

Manitoba Hydro assumed energy-intensive negative GHG emissions technology like DACCS would be one of the last options pursued to net out remaining emissions that had not already been addressed through other means as discussed above. Table A5.12 presents Manitoba Hydro's assumptions related to use of DACCS and Industrial CCS and the assumed capture rate of GHG emissions.

Table A5.12 - DACCS and Industrial CCS Assumptions

CCS Technology	Energy Requirements	Capture Rate
DACCS	Requires 1,944 GWh/Mt CO_2 captured & stored (7 GJ consumed/tonne stored)[52]	N/A
CCS on Industrial Consumers (non-electricity generation)	833 GWh/Mt CO_2 captured & stored (3 GJ consumed/tonne stored)	90%

Figure A5.13 presents Manitoba Hydro's estimate of remaining GHG emissions, in 2050, under the 2-Medium load projection and 3-High load projection, excluding negative GHG emissions and electricity generation GHG emissions (additional breakdowns can be found in Appendix 7.2 – Modelling and Analysis Results).

Table A5.13 - Manitoba Economy Gross GHG Emissions in 2050 (million tonnes CO_2e)

Manitoba Economy GHG Emissions in 2050 (excluding any negative GHG emissions)	2-Medium Load Projection	3-High Load Projection
Combustion GHG Emissions – Excluding Reductions Due to Industrial CCS and Incremental Biofuels	7.7	5.7
Combustion GHG Emissions – Including Reductions Due to Industrial CCS and Incremental Biofuels	5.9	3.9
Non-Combustion GHG Emissions	5.9	5.9
Total Gross GHG Emissions	**11.8**	**9.8**

[49,50] https://www.iea.org/energy-system/carbon-captureutilisation-and-storage/direct-air-capture

[51] https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SR15_Full_Report_LR.pdf

[52] https://www.iea.org/energy-system/carbon-captureutilisation-and-storage/direct-air-capture

A note on negative emissions technologies

Manitoba Hydro acknowledges that there is considerable uncertainty as to whether sufficient negative GHG emissions via DACCS can be deployed to support a net-zero economy. However, it was assumed possible for analysis in the 2025 IRP in order to model potential net-zero economy futures and provide conservative estimates on electric loads required to support negative emissions. Manitoba Hydro will continue to monitor these technologies and assumptions, including government policies, and adapt its planning as needed as part of future Integrated Resource Plans.

In the 2025 IRP, Manitoba Hydro is not assuming that the utility would own, operate, or maintain any DACCS infrastructure in Manitoba needed to reach a net-zero economy in Manitoba. Assumptions were made for the sole purpose of understanding the potential load these negative emissions technologies would require, and the impact on the resources needed to supply the electricity to operate the technology.

While DACCS could potentially be deployed in Manitoba to help achieve net-zero economy targets, the use of DACCS as a placeholder in the 2025 IRP is not a validation of the technology as an option. Further research, development, and confirmation of the technology at scale with meaningful GHG emission removals is required.

There are alternative options for negative GHG emissions technology, including BECCS (more details are provided in Appendix 6 – Resource Options) and natural processes (i.e., afforestation, reforestation, soil carbon sequestration, biochar application to soils, ocean-based carbon dioxide removal, agroforestry, enhanced mineralization).[53] These options could, theoretically, replace DACCS in a net-zero economy without adding to the electric load requirements.

[53] https://www.myclimate.org/en/information/faq/faq-detail/what-are-negative-emissions/

5.11.2. Negative GHG Emissions Load Assumptions

Using DACCS as the proxy, Table A5.14 presents the increases in terms of annual electric energy load (GWh) and peak load (MW) required to net the GHG emissions given in Table A5.13 to zero. Table A5.14 also presents the projected system wide loads in 2050 for comparison.

Table A5.14 – **System-Wide and Negative GHG Emissions Load in Annual Electrical Energy (GWh) and Annual Peak Electrical Demand (MW) in 2050**

	2 - Medium Load Projection (net-zero economy)	3 - High Load Projection (net-zero economy)
Negative GHG Emissions Annual Electric Energy (GWh)	22,900	19,000
System-Wide Annual Electric Energy (GWh)	65,900	75,400
Negative GHG Emissions Annual Peak Electrical Demand (MW)	1,720	640
System-Wide Annual Peak Electrical Demand (MW)	10,500	14,400

The substantial, and disproportionate, reduction in annual peak electrical demand impact, due to negative GHG emissions load, from the 2-Medium load projection to the 3-High load projection (i.e., 1,720 to 640 MW) is explained by differing winter peak negative GHG emissions loading assumptions.

In both scenarios, the negative GHG emissions load can be strategically reduced during winter months to minimize its contribution to the winter peak (without adversely impacting Manitoba's overall economy); however, reducing winter load requires increased operation during the remainder of the year to ensure sufficient negative GHG emissions are produced and cumulative GHG emissions remain net-zero.

The optimal winter reduction depends on the characteristics of each load projection. In the 2-Medium load projection, analysis showed that reducing the negative GHG emissions load by up to 50% effectively lowered its coincident peak impact. Further reductions would have merely shifted the peak to another hour, offering no additional benefit. Therefore, a 50% winter capacity reduction was assumed.

In contrast, the 3-High load projection features a more pronounced winter peak — primarily due to increased assumed electrical space heating. This allowed for a deeper reduction in the negative GHG emissions load during peak periods before creating a new peak. As a result, an 80% winter capacity reduction was assumed for the 3-High load projection.

This difference in winter reduction assumptions explains why the annual peak electrical demand impact of the negative GHG emissions technology in the 3-High scenario was 63% lower than in 2-Medium, despite only a 17% reduction in the total quantity of negative GHG emissions required to achieve net-zero (See Table A5.15).

The 2050 system wide annual peak in 3-High load projection (14,400 MW) is 3,900 MW higher than the 2050 system wide annual peak in 2-Medium load projection (10,500 MW), even though 2-Medium load projection negative GHG emissions load's impact is 1,080 MW greater. This highlights that:

- A higher negative GHG emissions load assumption is not deterministic of a higher system wide load assumption.
- If Manitoba Hydro had assumed a 50% winter capacity reduction for 3-High load projection, instead of an 80% reduction assumption, the 2050 system peak would have been around 5,000 MW greater than that of the 2-Medium load projection (instead of 3,900 MW).

Table A5.15 - Load Impact of Negative GHG Emissions Load in 2050 – Load Projection Comparison

Negative GHG Emissions Load	2-Medium Load Projection	3-High Load Projection	Difference
Total Gross GHG Emissions	**11.8**	**9.8**	**17%**
Annual Electrical Energy Impact (GWh)	22,900	19,000	17%
Annual Peak Electrical Demand Impact (MW)[54]	1,720	640	63%

[54] This represents the impact (in MWs) of negative GHG emissions load during the system's coincident peak.

6 | Load Projection Sensitivity

6.1. Introduction

During Round 1 engagement, Manitoba Hydro heard that the IRP should consider what is required to eliminate fossil fuel use in the ground transportation and space heating sectors, which would result in deeper GHG emission reductions in the transportation and stationary combustion sectors. In response to this feedback, Manitoba Hydro prepared a Load Projection Sensitivity that assumed Manitoba's economy eliminated fossil fuel consumption in Manitoba's ground transportation and space heating sectors.

The 3-High load projection assumed deep reductions in fossil fuel consumption in Manitoba's economy, within the boundaries of the guiding principles used to develop the three load projections. To establish the Load Projection Sensitivity, Manitoba Hydro had to move away from those guiding principles; to meet the pace of change required in the Load Projection Sensitivity, the following guiding principles were not considered:

- Limit the premature removal of existing systems that have not reached end of life. To eliminate internal combustion engine ground vehicles and natural gas space heating, vehicles and heating systems were replaced before their end of life. This premature replacement extended to other natural gas appliances, meaning if a customer replaced a furnace, they also replaced other natural gas-fired appliances like water heaters, ovens, stoves, and fireplaces.
- Relatively sustainable growth of industries/skilled labour. To meet the pace of change and eliminate fossil fuels in these sectors, industries had to rapidly increase installations and sales of new technologies. After reaching the target, there would be a steep reduction in demand in Manitoba, posing challenges for industries.
- Manitoba will not risk public safety to achieve a net-zero economy. To meet the pace of change of the Load Projection Sensitivity, under very rapid load growth it is uncertain whether Manitobans will continue to have a reliable supply of energy in the long-term and if all the capacity resources needed to ensure reliability could be built quickly enough.

6.2. Ground Transportation Assumptions in Load Projection Sensitivity

For the Load Projection Sensitivity , it was assumed that there would be no internal combustion engine ground vehicles in Manitoba by 2049/50. All other transportation assumptions, except for related biofuel assumptions discussed below, are the same as 3-High load projection. Additional reductions in fossil fuel consumption in the rail, marine, and aviation transportation sectors were not considered in this Load Projection Sensitivity. This Load Projection Sensitivity added approximately 5,000 GWh of EV charging load by 2049/50 as compared to the 3-High load projection. For the Load Projection Sensitivity, the EV sales percentage by vehicle type are shown in Figure A5.20, the electricity consumption by load projection is shown on Figure A5.21, and the peak impact is shown on Figure A5.22.

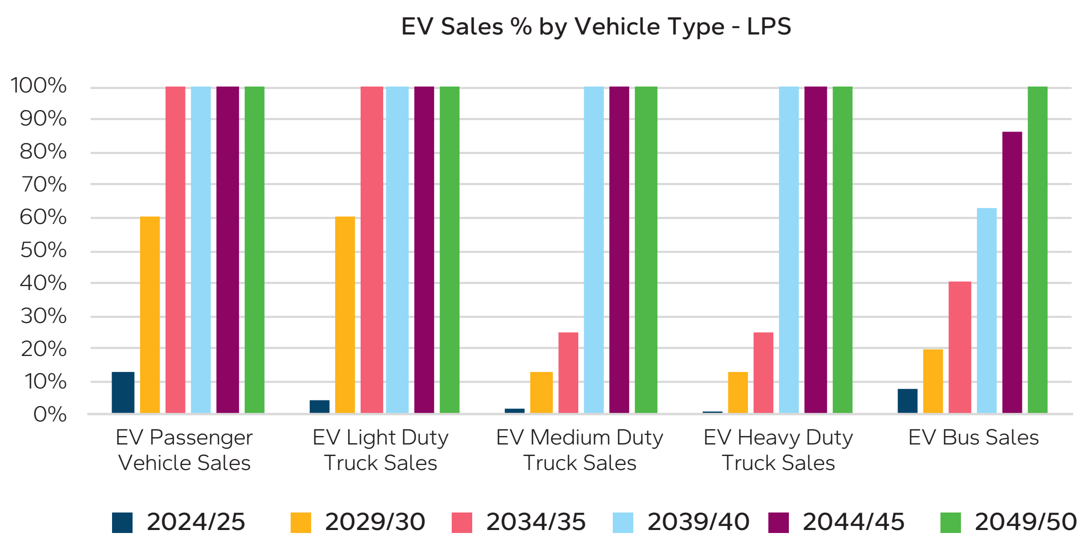


Figure A5.20 - ZEV Sales % by Vehicle Type – Load Projection Sensitivity

Figure A5.21 - ZEV Electricity Consumption for Load Projection Sensitivity

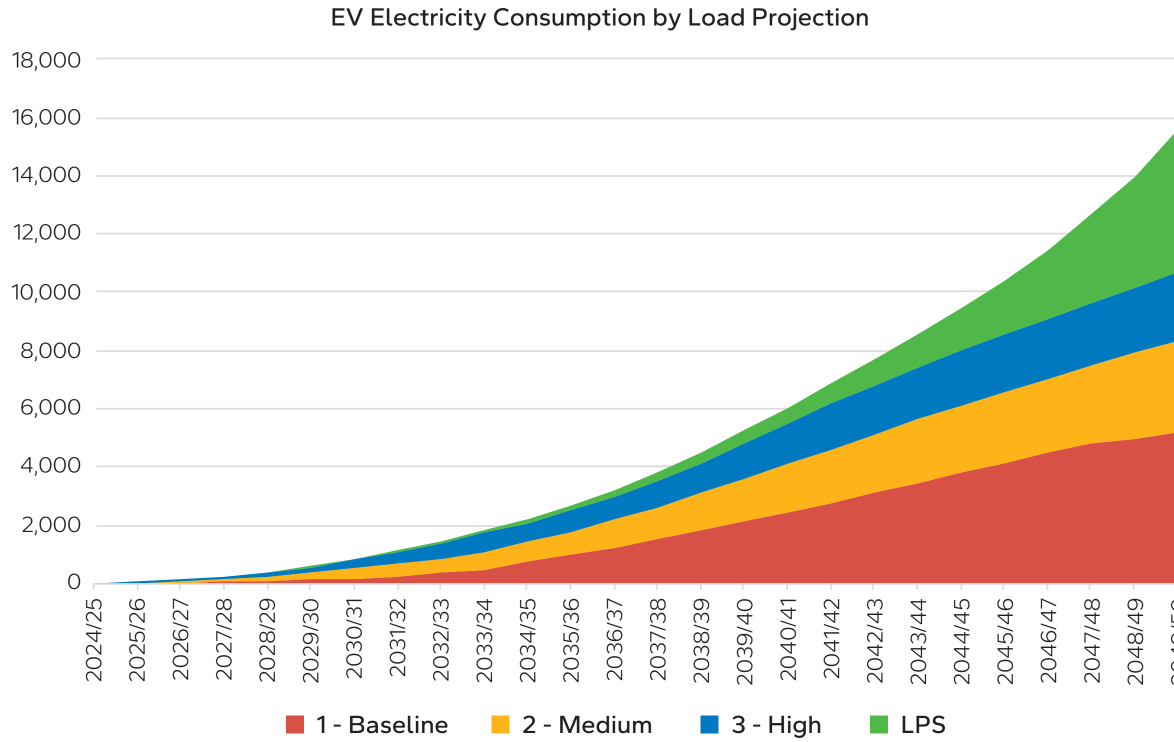
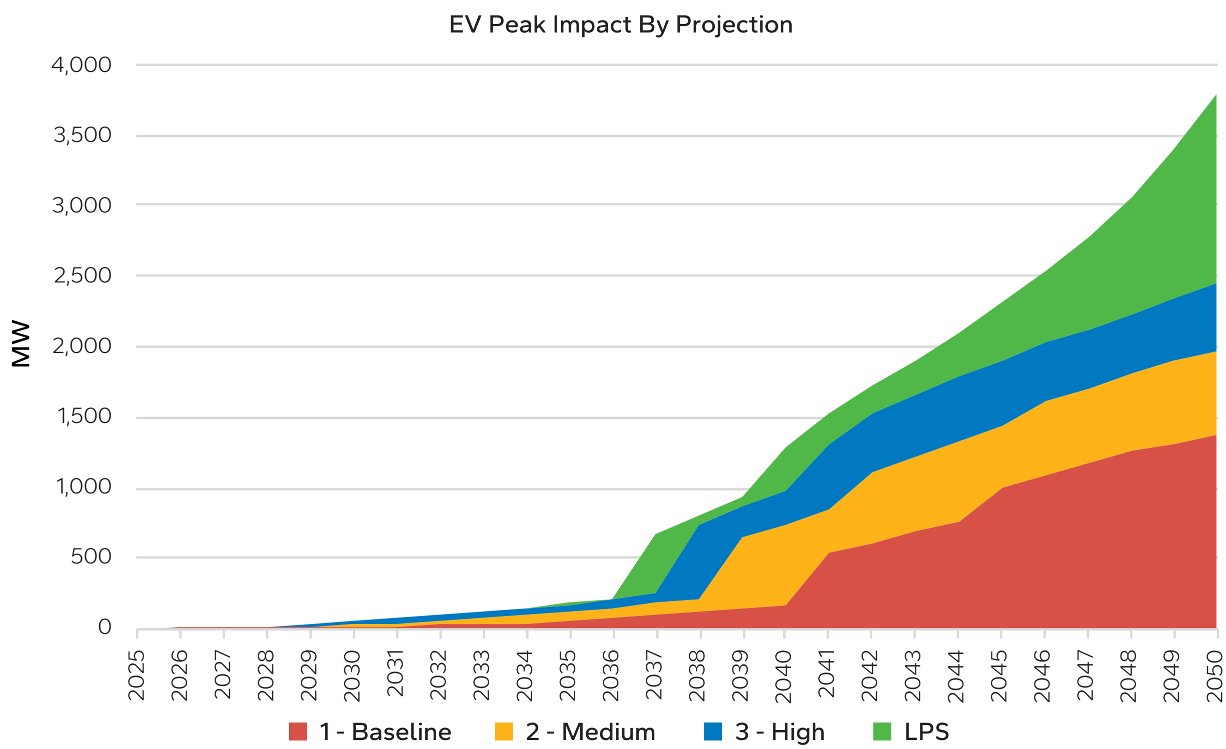


Figure A5.22 - ZEV Peak Capacity for Load Projection Sensitivity

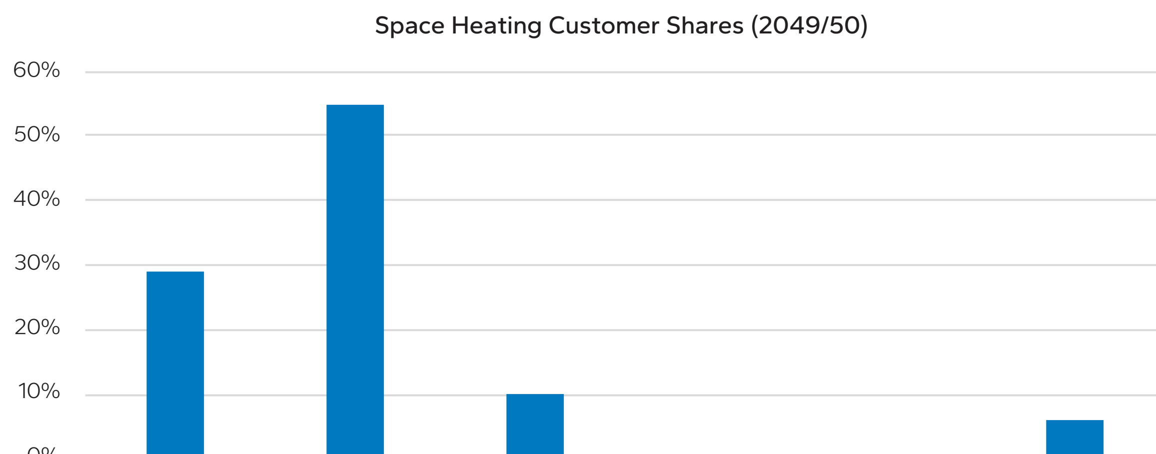


6.3. Space Heating Assumptions in Load Projection Sensitivity

In the Load Projection Sensitivity, Manitoba Hydro assumed that fossil fuel consumption for space heating and related appliances will be eliminated for residential, commercial, and small industrial customers by 2049/50. In the Load Projection Sensitivity, as in the 3-High load projection, new customers cannot install natural gas appliances after 2030, and existing customers can't replace natural gas systems that reach end of life after 2034/35. The breakdown of space heating options in the Load Projection Sensitivity is shown in Figure A5.23.

To fully eliminate fossil fuel use for space heating, an additional 110,000 natural gas heating systems must be replaced prematurely, before reaching end of life. The Load Projection Sensitivity also assumed that customers will transition to more efficient electric space heating systems over time, including dual electric systems and ground source heat pumps.

A limited number of large industrial natural gas customers remain after 2049/50.



	All Electric	Dual Electric System	Ground Source Heat Pump	Dual Fuel System	Natural Gas	Other
3-High Load Projection	29%	55%	10%	0%	0%	6%

Figure A5.23 - Heat System Breakdown for Load Projection Sensitivity

6.4. Additional Load Projection Sensitivity Loads

As in the 2-Medium and 3-High load projections, the Load Projection Sensitivity assumes Manitoba's economy achieves a net-zero economy from 2050 onwards. As discussed previously, a net-zero economy was assumed to result in some additional electric loads not accounted for in the 1-Baseline load projection, determined as part of a GHG emissions balance analysis.

In addition to assumptions being modified for ground transportation and space heating, changes to Manitoba's biofuel and hydrogen production, industrial CCS, and negative GHG emissions technology were considered as well.

Table A5.16 presents Manitoba Hydro's estimate of GHG emissions, in 2050, under the 3-High load projection and the Load Projection Sensitivity, excluding negative GHG. The assumptions in Load Projection Sensitivity results in the gross Manitoba GHG emissions being 3 million tonnes lower in 2050 as compared to the 3-High load projection – as with other load projections developed to study a net-zero economy in Manitoba, the Load Projection Sensitivity meets a net-zero economy in 2050.

Table A5.16 - Manitoba Economy Gross GHG Emissions in 2050 (million tonnes CO_2e)

Manitoba Economy GHG Emissions in 2050 (excluding any negative GHG emissions)	2-Medium Load Projection	3-High Load Projection
Combustion GHG Emissions – Excluding Reductions Due to Industrial CCS and Incremental Biofuels	5.7	1.6
Combustion GHG Emissions – Including Reductions Due to Industrial CCS and Incremental Biofuels	3.9	0.9
Non-Combustion GHG Emissions	5.9	5.9
Total Gross GHG Emissions	**9.8**	**6.8**

The two tables below present the load impacts, in terms of annual electrical energy (Table A5.17) and peak load (Table A5.18), resulting from the additional loads assumed in the net-zero economy futures for both the 3-High load projection and the Load Projection Sensitivity.

Table A5.17 – Additional Loads: Annual Electrical Energy (GWh) in 2049/50

2049/50 Load	3-High Load Projection	Load Projection Sensitivity
Incremental Biofuel Production	2,060	450
Incremental Industrial CCS	720	720
Negative GHG Emissions	19,080	13,270

Table A5.18 – Additional Loads: Annual Peak Electrical Demand Impact (MW) [55]

2049/50 Load	3-High Load Projection	Load Projection Sensitivity
Incremental Biofuel Production	260	60
Incremental Industrial CCS	90	90
Negative GHG Emissions	640	440

Biofuel production is lower under the Load Projection Sensitivity, compared to the 3-High load projection, as the use of some biofuels is restricted as follows:

- As the Load Projection Sensitivity eliminates the consumption of gasoline for transportation in Manitoba, it was also assumed that incremental ethanol production would be eliminated due to the challenges with E100 vehicles.
- In a Load Projection Sensitivity economy, it would be more challenging to integrate biomethane into the Manitoba natural gas system as only limited segments would remain to serve a limited number of large industrial customers; however, Manitoba Hydro assumed the same level of biomethane production as in the 3-High load projection, as injection into either the remaining distribution segments or the TCPL Mainline is plausible. Additional electrical energy would likely be required for biomethane compression into higher pressure systems, which was not quantified for this Load Projection Sensitivity.

The Load Projection Sensitivity assumed the same level of industrial Carbon Capture and Sequestration (CCS) was in place in Manitoba, as assumed for the 3-High load projection, since both industrial fossil fuel use and industrial process GHG emissions were unaffected by the parameters of the Load Projection Sensitivity.

[55] This represents the impact (in MWs) of these loads during the system's coincident peak.

For the Load Projection Sensitivity, no additional hydrogen production was assumed to be required to support either the ground transportation or space heating sectors for the following reasons:

- For the Load Projection Sensitivity, all incremental zero GHG emission vehicles (ZEVs), compared to the 3-High load projection, were assumed to be EVs. While it is highly uncertain whether this will be technologically possible, it was assumed to be possible for the purpose of the Load Projection Sensitivity. Had Manitoba Hydro assumed larger adoption rates for fuel cell hydrogen vehicles, the increase in ground transportation load would have been higher.
- The Load Projection Sensitivity assumed a consistent assumption as before that hydrogen would not be used for space heating as it is more energy efficient to reduce GHG emissions with the electrification of space heating than displacing natural gas with hydrogen. Had Manitoba Hydro assumed hydrogen heating as a space heating option, the increase in space heating load would have been higher.

Since Manitoba's economy in the Load Projection Sensitivity is assumed to have lower combustion GHG emissions, the Load Projection Sensitivity assumes about 30% less annual electric energy (GWh) is required to power negative GHG emissions in 2050. The annual electricity energy (GWh) required to net non-combustion GHG to zero (11,460 GWh) was unchanged by the parameters of the Load Projection Sensitivity.

Matching the 3-High load projection, it was assumed that negative GHG emissions load in the Load Projection Sensitivity would be reduced by 80% during the winter to minimize the impact on annual peak electrical demand. Since the impact of negative GHG emissions load on annual peak electrical demand was relatively low for the 3-High load projection, further reductions in impact under the Load Projection Sensitivity were also relatively low: the annual peak electrical demand impact of negative GHG emissions load under the Load Projection Sensitivity was only about 200 MW less (refer to Table A5.18).

Other assumptions related to additional loads match the details previously provided for the 3-High load projection.

6.5. Load Projection Sensitivity Overview

Load projection sensitivity creates an increase in energy consumption prior to 2049, and with the additional energy needed in 2050 to power negative GHG emissions technology, ends up slightly higher than the 3-High load projection, as shown in Figure A5.24 - Load Projection Sensitivity – Electrical Energy.

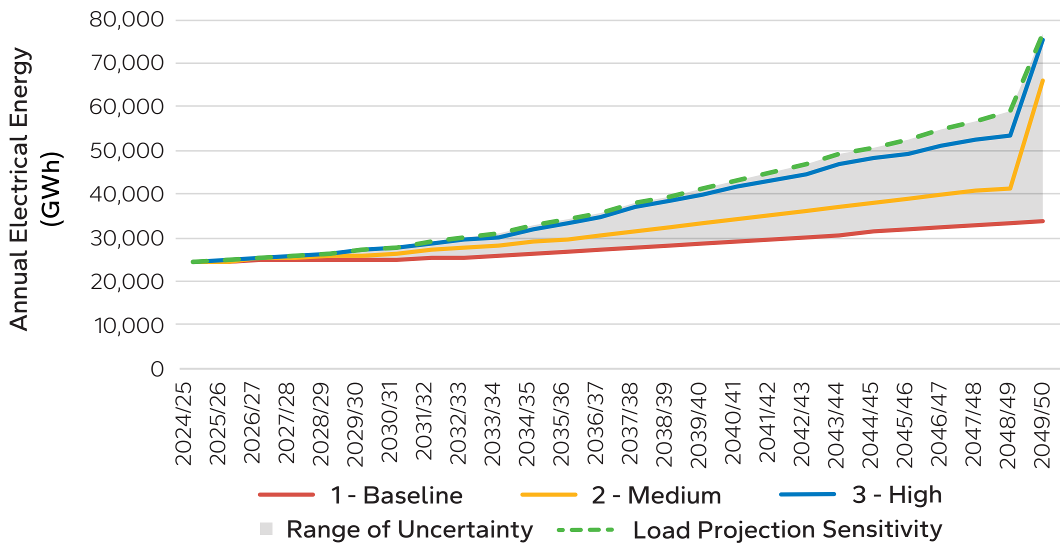


Figure A5.24 - Load Projection Sensitivity – Electrical Energy

The most significant difference between the 3-High load projection and the Load Projection Sensitivity is the resulting increase in annual peak electrical demand requirements. Compared to 3-High load projection, an additional 3,000 MW of capacity by 2049/50 is needed during periods of highest energy consumption in Manitoba as shown in Figure A5.25. The 2-Medium load projection, which also assumes a net-zero economy in 2050, has about 7,000 MW less peak demand in 2050 than the Load Projection Sensitivity.

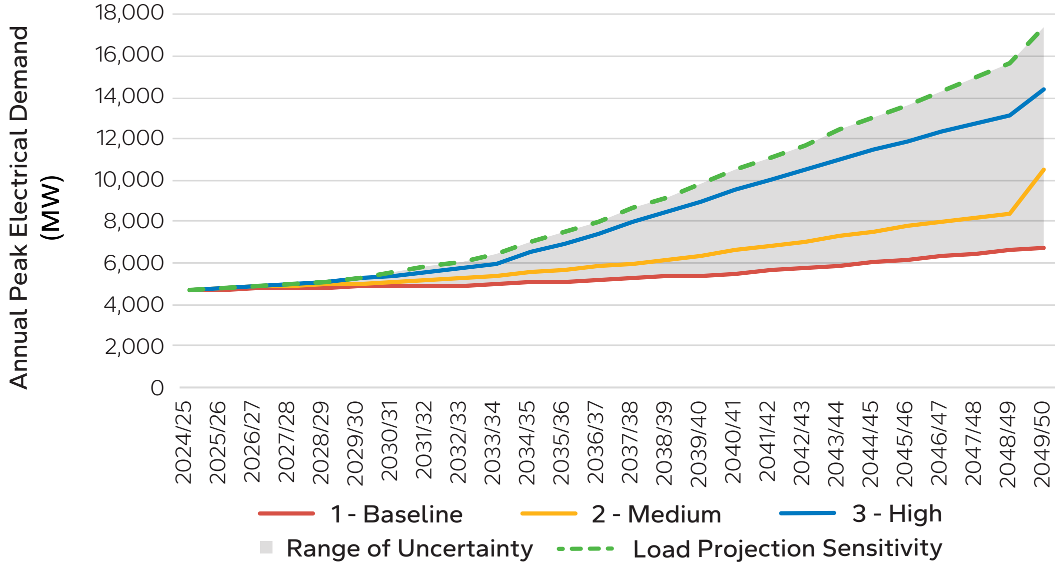


Figure A5.25 - Load Projection Sensitivity – Electrical Demand

As shown in Figure A5.26, by 2049/50 the Load Projection Sensitivity cuts provincial annual natural gas consumption by nearly half, compared to the 3-High load projection. Some natural gas consumption remains as Manitoba Hydro assumed some natural gas would remain in Manitoba's industrial (i.e., non-space heating) sectors for the Load Projection Sensitivity.

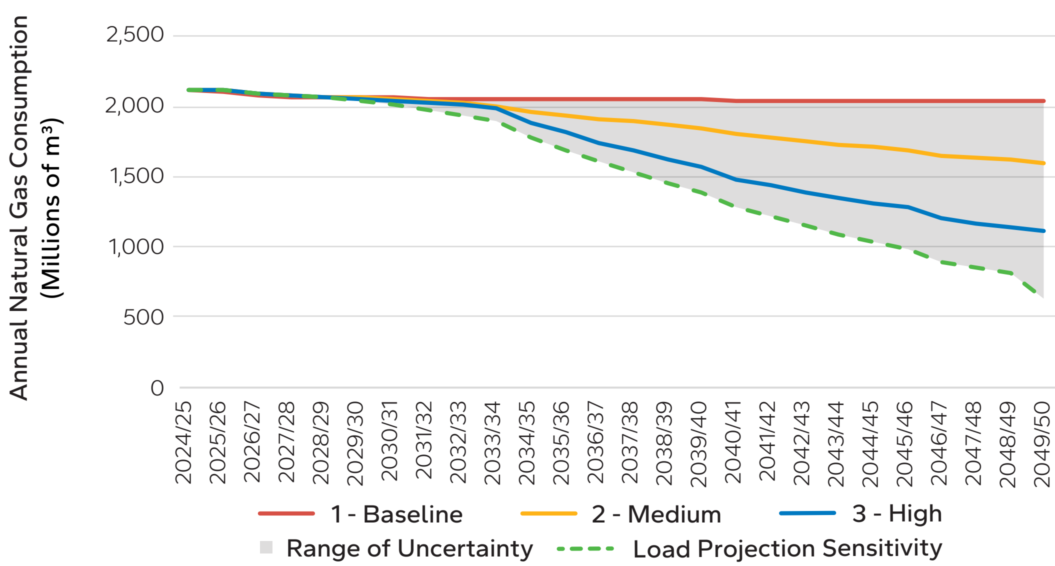


Figure A5.26 - Load Projection Sensitivity - Natural Gas Consumption

6.6. Potential Risks

Aiming for no fossil fuel consumption in ground transportation and space heating, while suspending some of the guiding principles used to develop the 2-Medium load projection and 3-High load projection, introduces significant execution risks that need to be addressed. First, the willingness of Manitobans to prematurely replace products before their end of life. Secondly, the potential for accelerated market demand to drive up prices, and the supply chain and skilled labour market's ability to meet increased demand. Additionally, industries heavily involved in the transition, such as heating, ventilation, and air conditioning (HVAC), may face a significant reduction in market demand post-2050. There are also challenges and affordability concerns for industrial and commercial customers in finding non-fossil alternatives for currently used natural gas appliances. Finally, it is uncertain whether adequate zero GHG emission vehicle (ZEV) technology will exist to allow for conversion of all ground transportation, considering no ZEV options currently exist for some medium and heavy-duty vehicle types.