footprint

Science North

Net Zero Carbon Plan

For:

Science North & Dynamic Earth

Project Location:

100 Ramsey Lake Road

122 Big Nickel Road

Footprint Project Number:

25026-001

Date:

2025-03-31

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Executive Summary

PURPOSE

The purpose of this investigation is to analyze the current energy consumption and greenhouse gas (GHG) emission performance and determine a viable path to Net Zero Carbon emissions for Science North and Dynamic Earth for Scopes 1 and 2 emissions.

SITE OVERVIEW

Science North operates Canada's 1st and 7th largest science centres located in Sudbury, Ontario. The larger of the two centres – Science North is located at 100 Ramsey Lake Road and Dynamic Earth – the smaller centre – is located at 122 Big Nickel Road. The gross floor areas (GFA) for Science North and Dynamic Earth are 200,000 ft^2 and 40,000 ft^2, respectively. Both buildings have solar photovoltaic (PV) arrays that generate electricity on their site. Both buildings use natural gas and electricity for energy consumption.

OVERALL ENERGY AND GHG PERFORMANCE

Table 1 shows the energy consumption and GHG emissions for the Baseline Year for both sites.

TABLE 1: BASELINE ENERGY USE AND GHG EMISSIONS

Site	Electricity Consumed (kWh)	Electricity Generated (kWh)	Total Effective Electricity Consumption (kWh)	Natural Gas (ekWh)	GHG Emissions (TCO_2e)	GHG Intensity ($kgCO_2e/ft^2$)
Science North	2,016,681	139,695	1,876,986	2,531,688	509	27.9
Dynamic Earth	393,205	66,183	327,022	509,577	101	29.1

A Business-As-Usual (BAU) scenario was developed for both sites wherein an estimation of GHG emissions over time is calculated based on like-for-like replacements of equipment, changes to the carbon intensity of Ontario's electricity generation, changes to GFA, and increase in average temperature over time. For Science North, a decrease in GHG emissions of 5% is expected in the BAU scenario. For Dynamic Earth, a 1% increase in GHG emissions is expected.

NET ZERO CARBON MEASURES AND TIMELINE

This Plan outlines how both sites will achieve Net Zero Carbon by 2050. Based on the current expected decarbonization timeline, it is expected that Science North will be fully electrified by 2036 – 14 years ahead of the 2050 deadline, and Dynamic Earth will be electrified shortly after in 2042. The measures and their implementation dates are subject to change based on available capital funding and should be revisited at a minimum every five (5) years. Through the implementation of energy conservation measures (ECMs), there is an expected GHG emissions reduction of 100% relative to the Baseline Year at both sites. There are two interim targets to assist in tracking the GHG emissions reductions up to 2050. Table 2 summarizes the GHG reduction targets for both sites.

TABLE 2: GHG EMISSIONS TARGETS

Site	Scope 1 GHG Emissions (TCO_2e)	Scope 2 GHG Emissions (TCO_2e)	2035 Target (% Reduction)	2045 Target (% Reduction)	2050 GHG Target (TCO_2e)	2050 GHG Target (% Reduction)
Science North	464	45	40%	90%	0	100%
Dynamic Earth	93.5	7.8	20%	90%	0	100%
Both Facilities (Net Zero Challenge)	**557.5**	**53.8**	**45%**	**90%**	**0**	**100%**

These targets are supported by a series of recommended energy conservation measures (ECMs) outlined in this Plan. The focus of the ECMs is to reduce the total GHG emissions. The timing of the retrofits is informed by existing Capital Plans and the observed condition of the current equipment. The planned building upgrades have been included in the Net Zero Carbon Plan to measure their expected impact on GHG emissions.

A summary of the recommended measures is presented for Science North (Table 3) and Dynamic Earth (Table 4). Details that describe how the measures are to be implemented can be found in the Energy Conservation Measures section of the Plan. Figure 1 shows the expected reduction in GHG emissions over time for both sites compared to the BAU case.

TABLE 3: RECOMMENDED MEASURES WITH SAVINGS AND COSTS – SCIENCE NORTH

ECM	Natural Gas Reduction (m^3/yr)	Electricity Reduction (kWh/yr)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction (% of Baseline)	Utility Cost Reduction 2025-2050	Capital Costs	Implemented Year
Quick Wins	35,187	-41,977	1,605	11%	$580,540	$657,500	2027
Window Upgrades	4,391	58,000	253	6%	$420,688	$2,000,000	2026
Lake Water Cooling	0	74,696	29	4%	$337,300	$800,000	2032
Water-Source Heat Pump	111,355	-308,870	3,970	37%	$898,949	$4,750,000	2032
Solar PV Array	0	131,478	413*	10%	$383,514	$200,000	2040
Air-Source Heat Pump	93,675	-733,404	2,582	32%	$(1,061,636)	$1,875,000	2036
Total	**244,608**	**-820,077**	**8,853**	**100%**	**$1,559,355**	**$10,282,500**	

* - Uses the Marginal Emissions Factor for electricity

TABLE 4: RECOMMENDED MEASURES WITH SAVINGS AND COSTS – DYNAMIC EARTH

ECM	Natural Gas Reduction (m^3/yr)	Electricity Reduction (kWh/yr)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction (% of Baseline)	Utility Cost Reduction 2025-2050	Capital Costs	Implemented Year
Quick Wins	2,177	-5,239	100	3%	$22,948	$ 63,550	2027
Envelope Upgrades	2,980	0	124	5%	$58,758	$ 937,500	2030
Rooftop Unit Heat Pumps	34,630	-245,906	957	58%	$(367,027)	$ 623,250	2027-2042
Air-Source Heat Pump	9,448	-57,142	218	15%	$(7,547)	$ 769,250	2039
Solar PV Array	0	9,714	266*	20%	$22,771	$ 74,000	2040
Total	**49,235**	**-298,573**	**1,665**	**100%**	**$(270,096)**	**$ 2,468,550**	

* - Uses the Marginal Emissions Factor for electricity

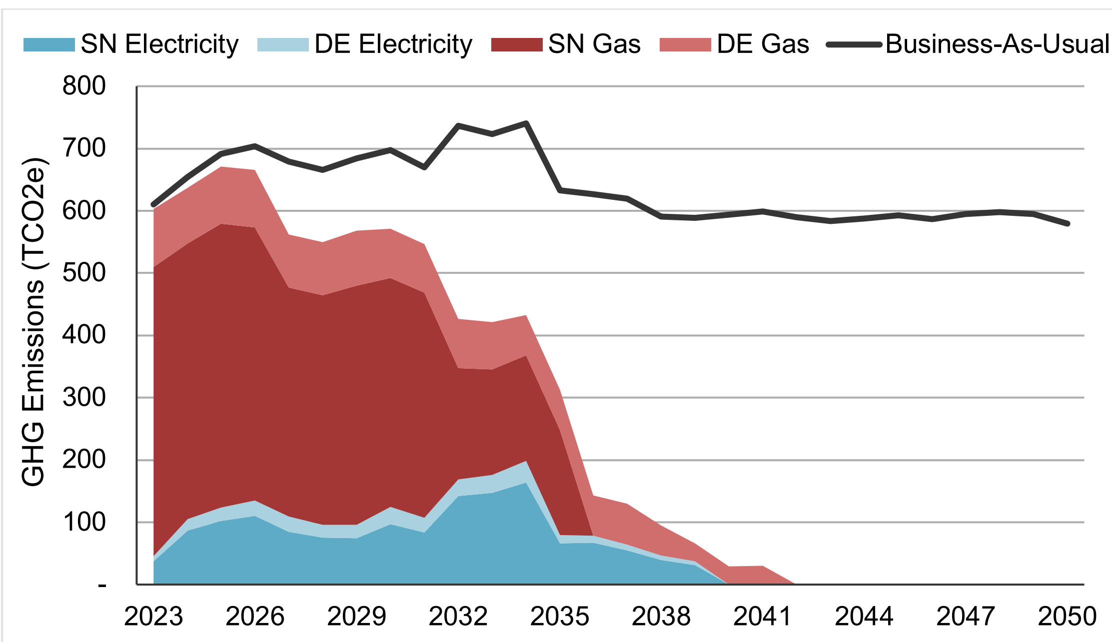


FIGURE 1: DECARBONIZATION TIMELINE

Glossary of Terms

Scope 1 Emissions – Greenhouse gas emissions emitted as a direct result of burning fossil fuels on-site. Natural gas burning equipment, gasoline and diesel used by the vehicle fleet and other equipment are all examples of Scope 1 emissions.

Scope 2 Emissions – Greenhouse gas emissions emitted through purchased energy. Emissions from the generation of electricity is an example of Scope 2 emissions.

Operational Emissions – Greenhouse gas emissions that are generated through the operation of energy systems of a building.

Greenhouse Gas – Gases that when released into the atmosphere trap heat that warms the Earth's surface. An increase in greenhouse gases emitted due to human activity has led to a climatic imbalance resulting in rising global average temperatures, changes in weather patterns, melting ice caps, rising sea levels, and other global impacts.

GHG – Greenhouse gas.

Carbon Dioxide Equivalent – The unit of measurement used to describe the climate warming potential of any chemical compound relative to carbon dioxide's heating capability. Expressed as CO_2e.

GFA – Gross floor area of a building.

GHGI – Greenhouse gas emissions intensity refers to the total amount of Scope 1 and 2 emissions a building produces divided by the gross floor area of the building. It is reported in kilograms of carbon dioxide equivalent per square meter (kg CO_2e/m^2).

ekWh – Equivalent kilowatt hour is a universal unit of energy consumption. It is most commonly used to compare energy consumption from different sources such as a comparison of natural gas and electricity.

GJ – Gigajoule is a unit of energy consumption. It is most commonly used to compare energy consumption from different sources such as a comparison of natural gas and electricity.

EUI – Energy use intensity refers to the total annual energy use in a building divided by the building's gross floor area. It is reported in equivalent kilowatt hours per square meter (ekWh/m^2).

Net Zero Carbon – Refers to when the total annual operational emissions (Scopes 1 and 2) is zero CO_2e. This is calculated by summing Scopes 1 and 2 emissions and subtracting emissions savings through renewable energy sold to the grid and any purchased offsets.

Introduction

OBJECTIVE

This Plan has been developed at the request of Science North to provide an analysis of the GHG emissions of two science centres and to develop a roadmap to achieve Net Zero Carbon by 2050. In line with the requirements of the Government of Canada's Net-Zero Challenge, two interim emissions reduction targets have also been developed. The boundary for this project includes Scopes 1 and 2 emissions for all of the buildings at Science North and Dynamic Earth.

The aim of the Plan is to:

- Establish the baseline energy use and GHG emissions of Science North and Dynamic Earth
- Review the planned mechanical and electrical upgrades for their impact on energy consumption and GHG emissions
- Identify new measures for carbon reduction
- Determine the ideal carbon reduction pathway to achieve carbon neutrality by 2050
- Establish a maximum of two interim GHG reduction targets that meet the requirements of the Government of Canada's Net-Zero Challenge

KEY DATES

The project began following a virtual kick-off meeting on December 17th, 2024.

The in-person site visit to Science North and Dynamic Earth was conducted on January 10th, 2025.

There was an in-person presentation delivered to the Senior Leadership Team and Green Team on February 19th, 2025.

PROJECT TEAM

TABLE 5: LIST OF PROJECT TEAM MEMBERS

Names	Firm	Role
Mitch Seguin	Science North	Director, Operations
Jessica Hall	Science North	Manager, Grants Programs, Green Team Chair
Garth Moote	Science North	Senior Manager, Facility Infrastructure
Sarkis Platis	Footprint	Project Lead, Auditor
Simon Sahi	Footprint	Quality Assurance Reviewer

Building Description – Science North

BUILDING INFORMATION

Science North is Canada's largest science centre originally constructed in 1984. The building is located at 100 Ramsey Lake Road in Sudbury, Ontario. The building has a gross floor area (GFA) of 200,000 ft^2. The science centre is effectively a collection of connected buildings. These buildings include the Entrance Building, Large Snowflake, Small Snowflake, and Education Building.

The Entrance Building (Figure 2) houses an IMAX theatre, gift shop, office spaces, an exhibits workshop, small cafeteria, and the Special Exhibit Hall. The Small Snowflake hosts the main cafeteria, a large programming space, and offices and an event space with its adjoining kitchen on the second floor. The Small Snowflake and the Entrance Building are connected via the Link – a space that includes tables and storage racks used daily by school groups. The Large Snowflake is a four-story building that houses the science centre's exhibits, office spaces, a live butterfly gallery, and the Vale Cavern – a theatre/event space used for larger gatherings. The Education Building is located in the space between the Entrance Building and the Large Snowflake and has additional office spaces. Figure 3 shows a satellite image of the science centre with the major areas labelled.

FIGURE 2: SCIENCE NORTH ENTRANCE BUILDING

The science centre has an occupancy schedule of 7:00am to 5:00pm for seven days of the week. The building is open during national holidays – apart from Christmas, Boxing, and New Year's days – and has an annual shutdown at the beginning of every year for general maintenance operation. The building also has a solar photovoltaic (PV) array that generates electricity on site. The electricity is sold directly back to the grid to reduce the effective electricity consumption of the science centre. Options for battery energy storage were explored to store and use the generated electricity in the building, but reliability issues resulted in this system being discontinued.

There is a surface parking lot on site in front of the building. There is a second surface parking lot around the back of the Entrance building primarily used by staff and for deliveries. There is dedicated parking for school and coach buses near the entrance roundabout used to park buses for traveling students and other large groups.

FIGURE 3: SCIENCE NORTH SCIENCE CENTRE LAYOUT

BUILDING ENVELOPE

The Entrance Building was previously an ice hockey arena before being extensively renovated. There is a significant southeast-facing window wall at the entrance of the building. Therefore, a significant amount of natural light and heat gain enters the Entrance Building. The Entrance Building and the Small Snowflake are connected via the Link. The Small Snowflake is hexagonal in shape with significant northeast-oriented glazing that faces Ramsey Lake. These windows do not benefit from solar heat gains. The Large Snowflake is connected to the Small Snowflake via an underground tunnel exposed to the bedrock. There is a significant window wall in the Large Snowflake that is four storeys tall, faces northeast, and takes up a portion of the roof area. The live butterfly gallery has a fully glazed façade and full skylight – making it effectively a sealed greenhouse. The Education Building and Large Snowflake are connected via an underground connection. The Education Building is a concrete construction with exterior insulation on a metal façade. All of the glazing at Science North is double-glazed.

The envelope is currently undergoing an upgrade at Science North. The windows in the second floor of the Small Snowflake are currently being replaced. The large window wall of the Large Snowflake is to be replaced in 2025, and the remaining windows are planned to be replaced in the coming years. The majority of the windows in the science centre are original to the building's construction and long past their expected life span. The new windows are expected to be installed in 2026. The energy savings from this upgrade have been calculated and included in the Net Zero Carbon Plan.

MECHANICAL SYSTEMS

In all areas – with the exception of the live butterfly gallery – the building is heated by two natural gas-fired boilers that distribute hot water to the air-handling units and to perimeter baseboard heaters in the office area. The boilers are PK Mach C3000 condensing boilers installed in the primary mechanical room located on the west side of the Entrance Building. The butterfly gallery has a dedicated hot water heating plant with three natural gas-fired condensing boilers. There is also a standalone spray humidification system that keeps the space at the optimal humidity for the butterflies. There are five packaged rooftop units that provide natural gas-fired heating to various spaces in the Entrance Building.

There is a central cooling plant also located in the Entrance Building's primary mechanical room. The single water-cooled chiller provides all of the space cooling for the science centre. There is one cooling tower located on the roof just outside of the mechanical room. Chilled water is distributed to all of the air-handling units in the science centre. The live butterfly gallery does not have mechanical cooling. The temperature setpoints in the space are high enough that cooling is not necessary.

Ventilation air is provided by 14 air-handling units. Each air-handling unit serves the specific area in which it is located. All but one air-handling unit has a return air stream which mixes with incoming outdoor air before being circulated back into the building. The only air-handling unit with no return air is used for make-up air in the kitchen area of the Small Snowflake. Ventilation air volumes are controlled by either time-of-day schedules or the concentration of carbon dioxide in the return air stream – the control method is dependent on whether the air-handling unit has a carbon dioxide sensor. There is no air-side heat recovery integrated in any of the air-handling units.

Domestic hot water heating is primarily supplied by a natural gas-fired domestic hot water located in the Link mechanical room. Domestic hot water is pumped throughout the facility via two booster pumps. The Butterfly Gallery is the only humidified space in the science centre. Domestic water is heated and sprayed as a mist directly into the Butterfly Gallery.

LIGHTING SYSTEMS

The lighting throughout Science North has recently been upgraded to LED. During the site review, it was revealed that approximately 99% of the lighting throughout the science centre had been converted to LED. The remaining non-LED bulbs would be changed to LEDs when the existing bulbs burn out.

The majority of the lighting is centrally controlled on a time-of-day schedule for each area. During the site review, it was revealed that the lighting control system is approximately 20 years old. While it appears to be working as intended, the level of control available through this system is limiting.

PROCESS LOADS

Process loads at Science North include:

- Office operations
- Operations of exhibits
- IMAX theatre operations
- Periodic loads related to the use of the Special Exhibit Hall
- Kitchen and food services
- Operation of Cavern

Process loads were not considered for possible ECMs for the Net Zero Carbon Plan. The energy and GHG emissions associated with these loads are still considered as part of the total building energy and emissions performance, and thus needed accounting.

Measures that have already been taken to help reduce process loads include controls on plug loads in the office spaces. These controls reduce the amount of electricity consumed in the office spaces during overnight hours.

BAS AND CONTROLS

Science North has a Building Automation System (BAS) provided by Honeywell. The BAS controls the schedules and setpoints for the mechanical systems in the science centre. This includes all of the air-handling units, the heating and cooling plants, the major pumps, baseboard heaters, and variable air volume boxes throughout the science centre. The BAS is able to set schedules and setpoints while also collecting important data trends to analyse the building's energy use. For this investigation, a review of the BAS and available trend data was gathered to gain a better understanding of the day-to-day operations of the science centre.

PLANNED BUILDING EXPANSION

At Science North, there is a concept design to expand the Lobby, Link, and Small Snowflake areas. This expansion would include the construction of a new multipurpose room and a retail space while expanding and reworking the existing food services area. The Lobby is also proposed to be changed to improve the visitor experience – although the proposed changes to the Lobby will not add a significant amount of new floor area to the building. The proposed expansion is included in this analysis. Since there is additional floor area proposed in the design, the energy required to heat, cool, and operate the new spaces is estimated and included in the analysis of the Net Zero Carbon Plan. Timing of the expansion has not been confirmed by Science North. For the purposes of this report, it is anticipated that the expansion will be completed in 2032.

Building Description – Dynamic Earth

BUILDING INFORMATION

Dynamic North is Canada's 7th largest science centre originally constructed in 2003. The building is located at 122 Big Nickel Road in Sudbury, Ontario. The building has a gross floor area (GFA) of 40,000 ft^2. The science centre has two storeys of public exhibit spaces, the Epiroc theatre with projection booth, the Vale Chasm, and a below-grade mine exhibit. Figure 4 shows the entrance to Dynamic Earth.

FIGURE 4: DYNAMIC EARTH ENTRANCE BUILDING

The primary use of the building is for an earth sciences and mining science centre and its associated amenities, including event spaces. The entrance area of the building includes a theatre, gift shop, and public washrooms. Through a short corridor, there is the food services space, exhibit space, offices, washrooms and a programming space. The west side of the building along with the lower floor contains exhibit galleries, as well as a programming space, smaller theatre, public washrooms and a mechanical room. The south side of the building is dedicated to the Vale Chasm (the Chasm). This space includes the entrance to the underground mine exhibit. Great lengths have been taken to keep this area authentic to a working mine for a realistic public experience.

The science centre has a typical occupancy schedule of 8:00am to 7:00pm seven days of the week. The building is open during most national holidays apart from Christmas, Boxing, and New Year's days. There is an annual shutdown at the beginning of every year for general maintenance operation. The building also has a solar PV array that generates electricity on site. The electricity is sold directly back to the grid to reduce the effective electricity consumption of the science centre.

There is a single surface parking lot on site in front of the building. There is dedicated parking for school and coach buses in a neighbouring small lot to park buses for traveling students and other large groups.

BUILDING ENVELOPE

The building envelope consists of an exterior layer of black sheet metal with layers of insulation and interior concrete block walls. All of the windows in the building are double pane units. The building envelope surrounding the Chasm does not have any interior insulation. As such, this space gets warm during the summer as there is significant heat gain from the black paint. The space also gets cold during the winter as a result of the lack of insulation. The space is kept at a setpoint temperature of 10°C – this is to help mimic the true conditions of a mine while not freezing the interior materials and equipment. The office space directly adjacent to the Chasm also does not have insulation within the wall. Therefore, this space is vulnerable to similar temperature swings of the Chasm.

There is a planned expansion of the museum that is expected to be completed in 2027. It is expected to increase the total gross floor area by 409m^2 – an increase of about 10% to the existing gross floor area. The planned expansion will incorporate a new events space with an associated food preparation area. This planned expansion and its associated increase in total energy consumption has been considered in developing the Net Zero Carbon Plan.

MECHANICAL SYSTEMS

The majority of the building areas are conditioned through the use of packaged rooftop units. In total, there are 13 packaged rooftop units at Dynamic Earth. These units provide heating, cooling, and ventilation air for the occupied spaces. Internal temperatures are controlled via wall-mounted thermostats. The thermostats had been recently upgraded to Honeywell smart thermostats that are able to be controlled remotely via an application on a cell phone. There are plans to install a Building Automation System (BAS) at Dynamic Earth.

There is a central boiler plant that provides building hot water. The boilers are natural gas-fired boilers that distribute hot water to various cabinet heaters located at various points of entry in the building. There are four Viessmann Vitodens 200-W boilers in the plant. The boilers were installed in 2019. The cabinet heaters are all locally controlled via wall-mounted thermostats. These units are not behind locked cases and are therefore vulnerable to manipulation from the public.

There is no central cooling plant in the building. All space cooling is from the packaged rooftop units. All rooftop units have DX cooling incorporated in their design. The rooftop units also provide all of the ventilation air for the building. Air balance is accomplished through dedicated exhaust air from the washrooms and kitchen exhaust being made up by the incoming ventilation air from the rooftop units.

Domestic hot water heating is supplied by a natural gas-fired domestic hot water heater located in the mechanical room that also houses the hot water boilers. There is no dedicated humidification in the building.

LIGHTING SYSTEMS

During the site review, it was revealed that approximately 99% of the lighting throughout the museum had been converted to LED. The only remaining bulbs to be changed would be done when those bulbs burn out. There is no central lighting control at Dynamic Earth. The vast majority of lights are controlled manually via wall-mounted switches. The lights are turned on and off by staff at the time of opening and closing of the science centre.

PROCESS LOADS

The majority of the process loads in the science centre are related to the operations of the centre. For the sake of this Net Zero Carbon Plan, process loads were not considered for possible ECM's. However, the energy and GHG emissions associated with process loads were still considered as part of the total and needed accounting.

Process loads at Dynamic Earth include:

- Office operations
- Loads related to the various exhibits
- Operating the theatre
- Kitchen and food services

BAS AND CONTROLS

As previously explained, the building has no central BAS. Space temperatures and schedules are all controlled via wall-mounted smart thermostats provided by Honeywell. Following a building controls study conducted in 2023, plans have been established to install a BAS at Dynamic Earth. This upgrade in building controls will improve the scheduling and temperature controls leading to energy savings. These savings have been estimated and included in the Net Zero Carbon Plan.

PLANNED BUILDING EXPANSION

At Dynamic Earth, there is a plan to expand the total size of the science centre through the construction of a new building at the south end of the site connected to the main building via an underground tunnel. The new building is slated to be a theatre space with food services and associated washroom. This is expected to increase the gross floor area of Dynamic Earth by 409 m^2. This expected expansion and its associated energy consumption has been incorporated in the Net Zero Carbon Plan. It is expected that this addition be completed by 2026.

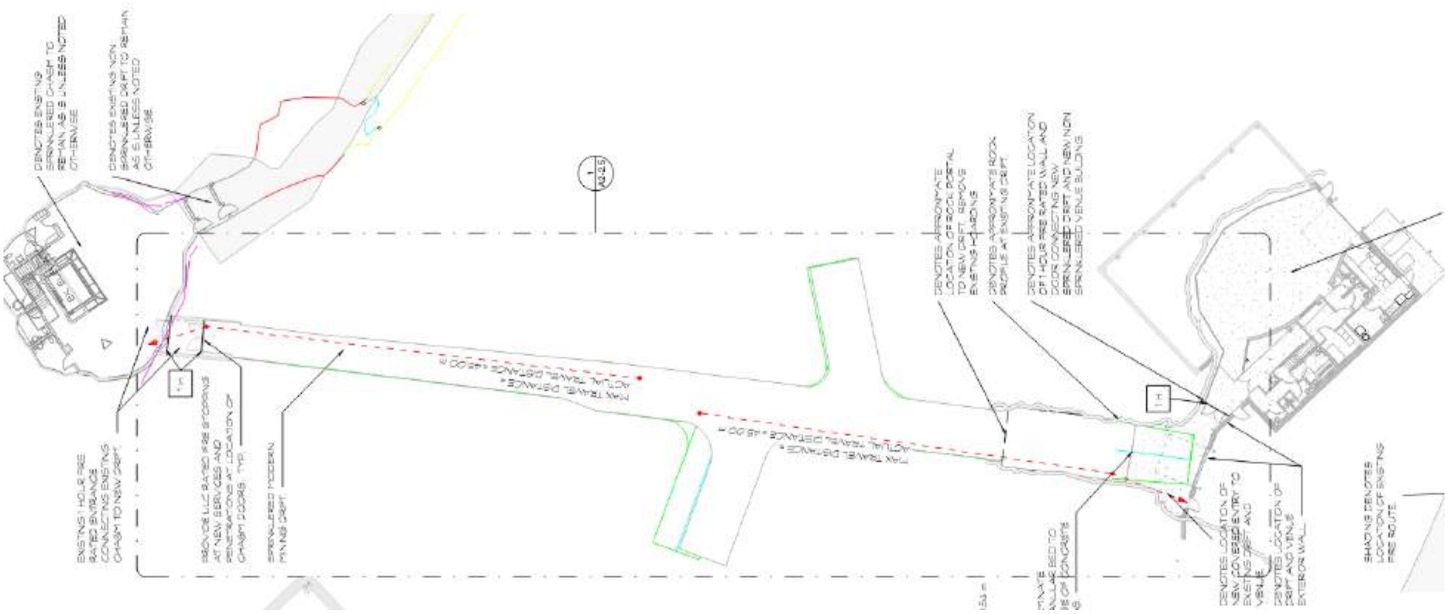


FIGURE 5: PROPOSED EXPANSION TO DYNAMIC EARTH

Historical Utility Data

Science North and Dynamic Earth each have a single incoming electrical utility meter responsible for the sites' electricity consumption. Both solar PV arrays have a dedicated meter that measures the amount of electricity generated and fed into the grid separately from the incoming electricity. There is also a single natural gas meter at each site that measures the site's natural gas consumption. Utilities are billed monthly for all energy types at both facilities.

DATA SUMMARY

Science North

The energy sources at Science North are electricity and natural gas. Consequently, these are the two sources of GHG emissions associated with the operation of the building. There is a solar PV array on site that generates electricity. This energy is included in calculating the total GHG emissions of the building. Annual energy and GHG emissions from 2021 to 2023 are presented in Table 6. The baseline period for this study is 2023.

TABLE 6: UTILITY CONSUMPTION – SCIENCE NORTH

Year	Electricity Consumed (kWh)	Electricity Generated (kWh)	Total Effective Electricity Consumption (kWh)	Natural Gas (ekWh)	Scope 1 GHG Emissions (TCO_2e)	Scope 2 GHG Emissions (TCO_2e)
2021	1,783,054	147,193	1,635,861	2,181,797	48	400
2022	1,907,692	144,056	1,763,636	2,531,656	58	465
2023	2,016,681	139,695	1,876,986	2,531,688	45	464

The baseline emissions for Science North are calculated to be 509 metric tonnes CO_2e (TCO_2e). This is calculated based on 2023 energy consumption and the published Ontario emissions factors for 2023. The majority of operational GHG emissions result from natural gas consumption on site – 91% of the total. However, natural gas represents slightly more than half of the total energy consumption in the building – 57%.

This difference in percentages is due to Ontario's electrical grid having a low GHG emissions factor – 24 g CO_2e/kWh in 2023[1]. For the equivalent amount of energy, natural gas currently emits over seven times the amount of carbon at 1,899 g CO_2e/m^3 (183.5 g CO_2e/ekWh)[2]. Due to its high carbon intensity relative to electricity, natural gas consumption is targeted in this Plan to reduce operational greenhouse gas emissions and achieve Net Zero Carbon by 2050.

Between 2025 and 2050, there is expected to be variation in the amount of GHG emissions associated with electricity generation in Ontario[3]. As a result of the ongoing refurbishment of the nuclear power plants, it is expected that there will be an increase in emissions as the natural gas electricity generators are expected to make up the difference until the

[1] Environment and Climate Change Canada Current Projections, electricity grid intensities: https://data-donnees.az.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/
[2] National Inventory Report for 2023 Natural Gas Emissions Factor in Ontario: https://publications.gc.ca/site/eng/9.506002/publication.html Part 2, Table A6.1-1
[3] Environment and Climate Change Canada Current Projections, electricity grid intensities: https://data-donnees.az.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/

nuclear plants are able to operate at their full capacity. Figure 6 shows the expected change in electricity emissions factor in Ontario over time.

This study utilizes a conversion factor of 10.639 ekWh per m^3 of natural gas[4]. This is based on the Energy Star Portfolio Manager Thermal Energy Conversions.

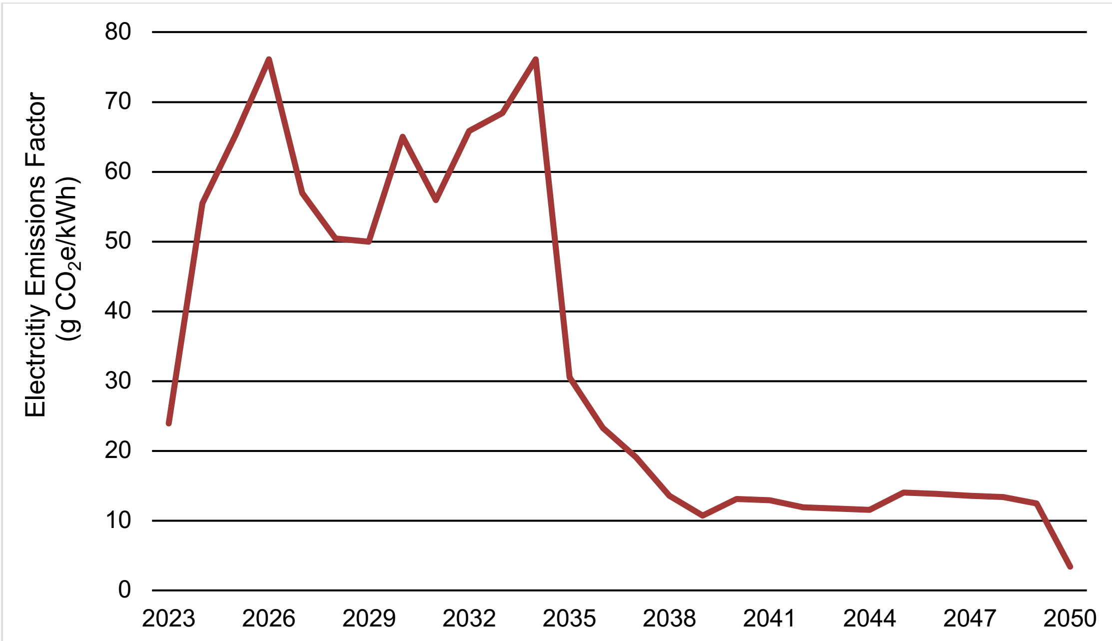


FIGURE 6: EXPECTED AVERAGE EMISSIONS FACTOR FOR ELECTRICITY GENERATION - ONTARIO

Dynamic Earth

As with Science North, the sources of energy consumption at Dynamic Earth are electricity and natural gas. There is a solar PV array on site that generates electricity and like Science North, the electricity generation is included in calculating the total GHG emissions of the building. Annual energy and GHG emissions from 2021 to 2023 are presented in Table 7. There is a significant anomaly in the energy generation in 2022. As such, that year was not considered for any further analysis. As with Science North the Baseline Year is 2023.

TABLE 7: UTILITY CONSUMPTION – DYNAMIC EARTH

Year	Electricity Consumed (kWh)	Electricity Generated (kWh)	Total Effective Electricity Consumption (kWh)	Natural Gas (ekWh)	Scope 1 GHG Emissions (TCO_2e)	Scope 2 GHG Emissions (TCO_2e)
2021	309,158	58,879	250,279	300,536	7.3	55.1
2022	Omitted					
2023	393,205	66,183	327,022	509,577	7.8	93.5

The baseline emissions for Dynamic Earth is calculated to be 101 TCO_2e. For reasons similar to Science North, natural gas consumption accounts for 92% of total GHG emissions while only consuming 61% of the total energy.

[4] Natural gas m^3 to ekWh conversion based on Energy Star Portfolio Manager Thermal Energy Conversions: https://portfoliomanager.energystar.gov/pdf/reference/Thermal%20Conversions.pdf

Marginal Emissions Factor

When calculating the GHG emissions from electricity consumption, it is important to make a distinction between the Average Emissions Factor (AEF) and the Marginal Emissions Factor (MEF). As explained above, the AEF is the average emissions related to the generation of electricity in Ontario. This value is expected to fluctuate between 2025 and 2050 as explained above. The MEF differentiates from the AEF because it only represents the GHG emissions impacts of changes in electricity consumption during peak and off-peak times. In Ontario, the marginal mode of electricity generation is a combination of natural gas plants, wind power, and hydroelectricity. Therefore, the MEF for Ontario is the emissions related to these forms of generation. As a result, the MEF is higher than the AEF. Estimations for Ontario's MEF are anticipated between 2025 and 2040 to be 320 gCO_2e/kWh generated[5].

The MEF can be used to calculate the potential GHG emissions reduction from electricity generation measures on-site. This includes installation of a combined heat and power system, or a solar PV array. The reasoning for this is because on-site electricity generation does not remove baseline electricity use, but is most effective during the peak times in the province. As a result, the electricity generated on-site (and therefore not generated by the province) removes electricity generated largely by natural gas plants – increasing the GHG emissions reduction associated with those measures. This is a common calculation method used in the industry and a more representative view of the emissions reduction associated with the on-site measures.

ELECTRICITY ANALYSIS

Science North

Annual electricity consumption and costs for Science North are shown in Table 8. As it can be seen, there has been a steady increase in total electricity consumption over time in the science centre. Although, the effects of the COVID-19 pandemic may be a significant factor in the reduced electricity consumption in 2021. 2023 was selected as the Baseline Year since it is the most recent full calendar year of data.

TABLE 8: ANNUAL ELECTRICITY CONSUMPTION AND COSTS

Year	Electricity Consumption (kWh)	Electricity Generation (kWh)	Electricity Average Cost ($/kWh)	GHG Emissions (TCO_2e)
2021	1,783,054	147,193	$0.143	47.4
2022	1,907,692	144,056	$0.148	58.2
2023	2,016,681	139,695	$0.148	44.9

The electricity consumption profiles from 2021 to 2023 are presented in Figure 7. It can be clearly seen that COVID-19 had an impact on electricity consumption in the science centre. It can also be seen that there is higher electricity consumption during the summer months, resulting from the increased space cooling demand in these periods. The electricity consumption is relatively stable outside of the summer months. The average electricity consumption cost for 2023 was $0.148/kWh.

[5] Marginal Greenhouse Gas Emissions Factors for Ontario, Electricity Generation and Consumption. Prepared by: Power Advisory LLC for Enbridge Gas Inc. October 2020. https://consortia.myescenter.com/CHP/Power_Advisory_Report_on_Marginal_Emission_Factors_for_Ontario_Electricity_Generation_Oct2020.pdf

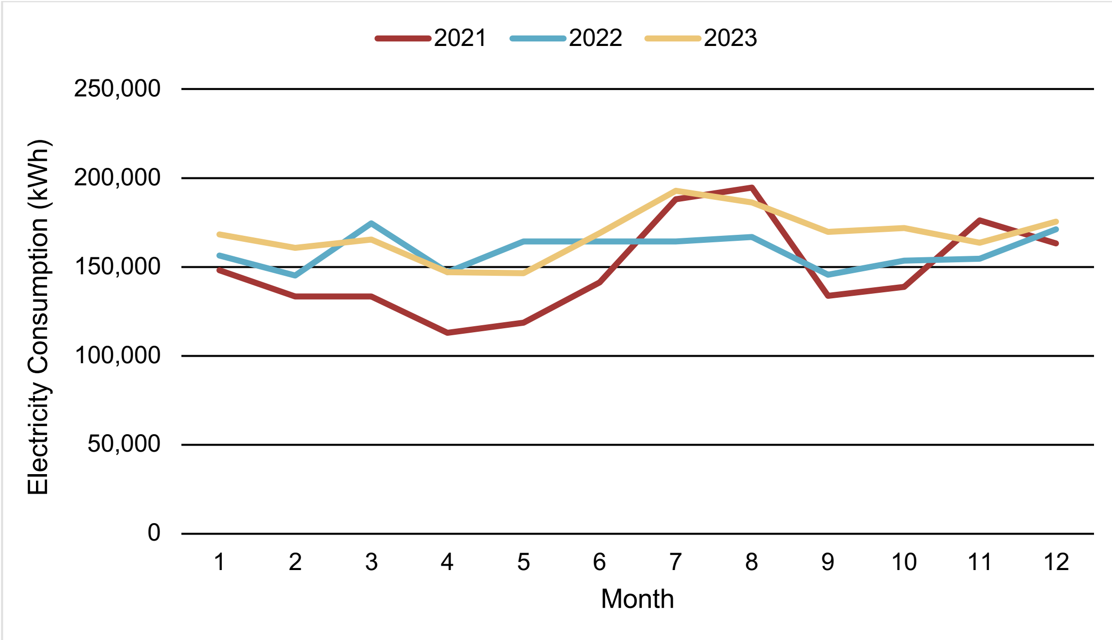


FIGURE 7: MONTHLY ELECTRICITY CONSUMPTION – SCIENCE NORTH

Dynamic Earth

Annual electricity consumption and costs for Dynamic Earth are shown in Table 9. The effects of the COVID-19 pandemic were a significant factor in the reduced electricity consumption in 2021. As the latest full calendar for which utility data is available, 2023 was selected as the Baseline Year. 2022 is the anomalous year where the recorded generation is higher than the electricity consumed. Therefore, the electricity generation and the GHG emissions for 2022 can be ignored.

TABLE 9: ANNUAL ELECTRICITY CONSUMPTION AND COSTS – DYNAMIC EARTH

Year	Electricity Consumption (kWh)	Electricity Generation (kWh)	Electricity Average Cost ($/kWh)	GHG Emissions (TCO_2e)
2021	309,158	58,879	$ 0.146	7.26
2022	Omitted			
2023	393,205	66,183	$ 0.151	7.82

The electricity consumption profiles from 2021 to 2023 are presented in Figure 8. Here it can be clearly seen that COVID-19 had an impact on electricity consumption in the science centre through the unstable nature of the electricity consumption. It can also be seen that there is higher electricity consumption during the winter months. This likely related to the increased fan energy from the rooftop units when running in heating mode. The average electricity consumption cost for 2023 is $0.151/kWh.

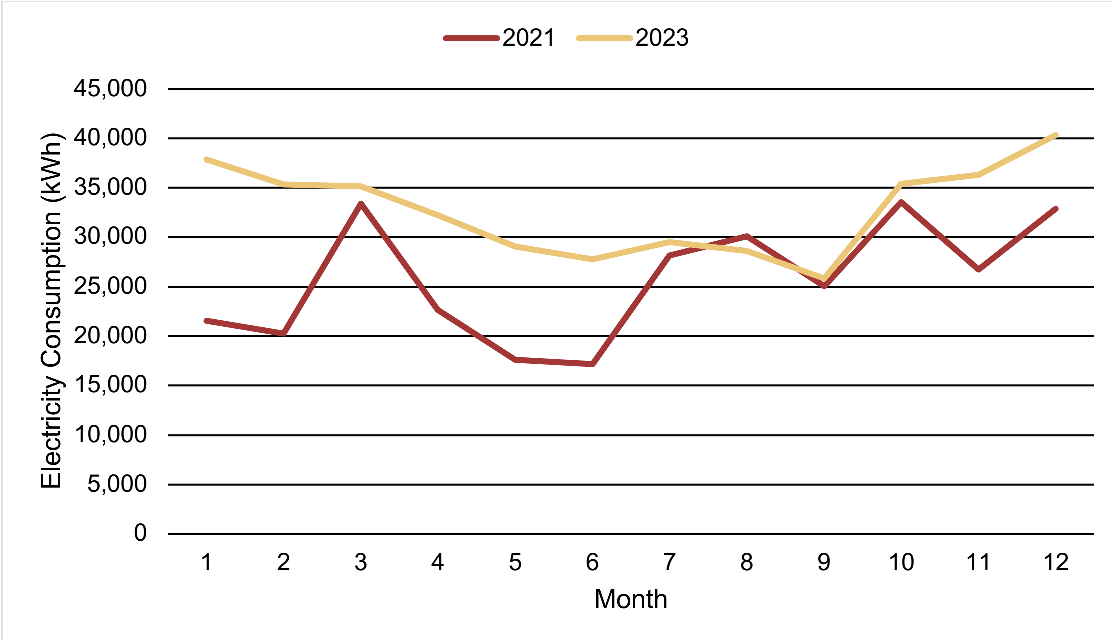


FIGURE 8: MONTHLY ELECTRICITY CONSUMPTION - DYNAMIC EARTH

ELECTRICITY GENERATION

Science North

In 2023, the solar PV array at Science North generated 139,695 kWh of electricity – 7% of the total electricity consumed by the science centre. The solar PV array is located in the open area between the Large Snowflake, Small Snowflake, and the Science Program Unit. Solar energy generation changes month-by-month throughout the year. As expected, electricity generation is highest during the summer months, and lower during winter. The concentration of sunlight is higher during the summer months compared to winter. Figure 9 indicates how electricity generation changes based on Cooling Degree-days. Higher Cooling Degree-days is an indication of warmer weather and is associated with an increase in electricity generation.

Electricity generation plays an important role in the overall Net Zero Carbon Plan for Science North. As the building systems will move away from natural gas and towards electricity, generation will become crucial for reducing total utility costs and GHG emissions. As such, opportunities to expand the existing PV array have been explored in this Plan. Furthermore, as Science North is involved in public education, displays of renewable electricity generation can also serve as educational exhibits related to sustainability and the role that nature plays in the operation of the science centre.

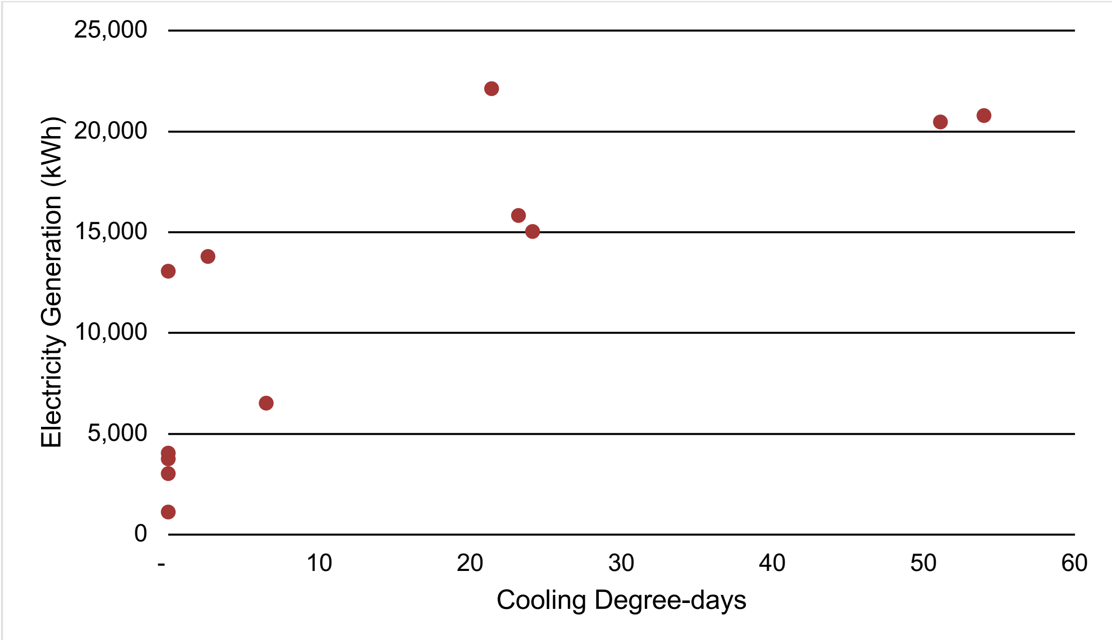


FIGURE 9: SOLAR PV GENERATION VS COOLING DEGREE-DAYS – SCIENCE NORTH 2023

Dynamic Earth

In 2023, the solar PV array at Dynamic Earth generated 66,183 kWh of electricity – 17% of the amount consumed by the museum. The solar PV array is located on the roof of the Chasm. As with Science North, electricity generation is highest during the summer months, and lower during winter. Figure 10 indicates how electricity generation changes month-by-month. For similar reasons, electricity generation plays an important role in the overall Net Zero Carbon Plan for Dynamic Earth. Opportunities to expand the existing PV array have been explored in this Plan.

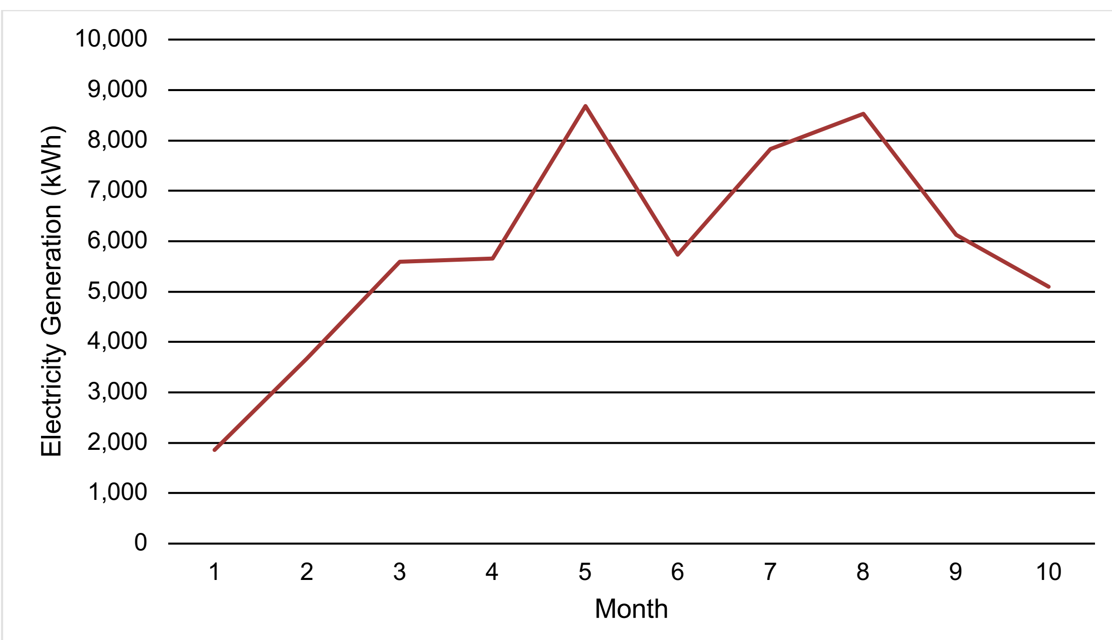


FIGURE 10: SOLAR PV GENERATION BY MONTH - DYNAMIC EARTH 2023

NATURAL GAS ANALYSIS

Science North

Annual natural gas consumption and costs are shown in Table 10. The increase in natural gas consumption is a result of 2022 and 2023 being colder overall compared to 2021. As with electricity, 2023 was selected as the Baseline Year for consumption and GHG emissions. There has also been a significant cost increase in natural gas since 2021. This is partially due to the continued escalation of the carbon tax in Canada, as well as increases resulting from the reduced global supply of natural gas. This cost escalation is continued into the future to project the utility cost savings of various ECM's involving natural gas for this analysis.

TABLE 10: ANNUAL NATURAL GAS CONSUMPTION AND COSTS – SCIENCE NORTH

Year	Natural Gas (m^3)	Natural Gas Cost Rate ($/$m^3$)	GHG Emissions (TCO_2e)
2021	210,802	$0.348	400.3
2022	244,604	$0.510	464.5
2023	244,608	$0.462	464.5

The natural gas consumption profiles from 2021 to 2023 are presented in Figure 11. It can be seen that the winter months consistently see higher rates of natural gas consumption compared to summer months. This is because natural gas systems at Science North are primarily for space heating. Therefore, it is expected that there is higher natural gas consumption in the winter months. In 2023, the baseload for natural gas consumption was 673 m^3 per month. This amount is a result of domestic water heating and service kitchen operations. The average natural gas consumption cost for 2023 is $0.462/$m^3$ ($0.045/ekWh).

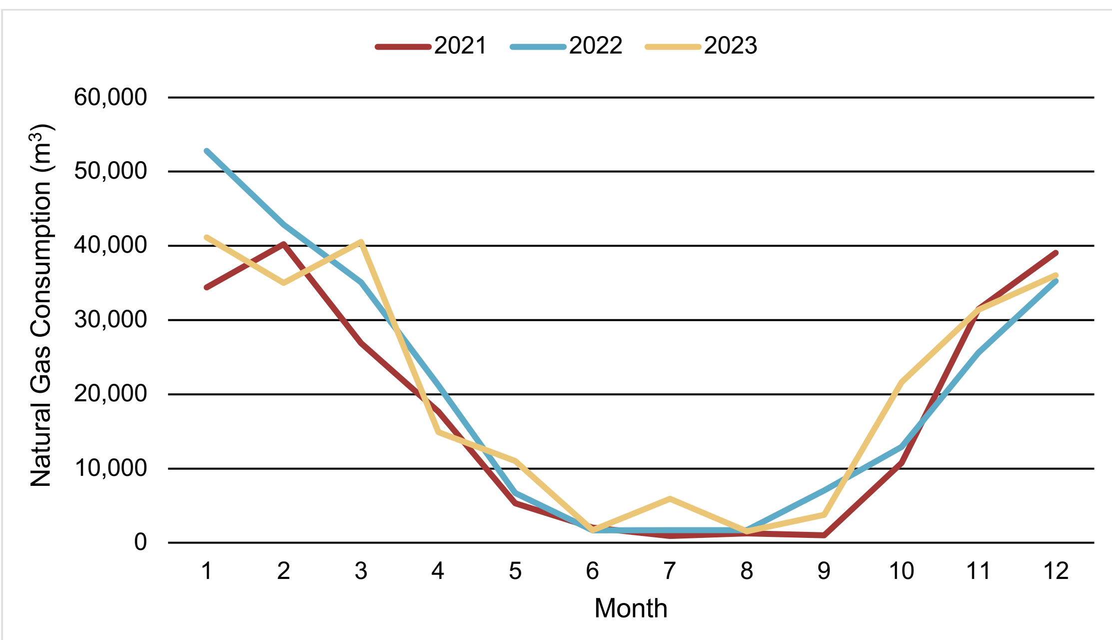


FIGURE 11: MONTHLY NATURAL GAS CONSUMPTION – SCIENCE NORTH

A linear regression analysis was conducted in RETScreen Expert to determine the level of dependence of natural gas consumption on outdoor weather considerations for Science North. Using the Baseline Year, the linear regression model results in an R-squared value of 0.90 – indicating a strong correlation between natural gas consumption and outdoor weather. Figure 12 shows the relationship of natural gas consumption and Heating Degree-days – an indicator of outdoor weather conditions.

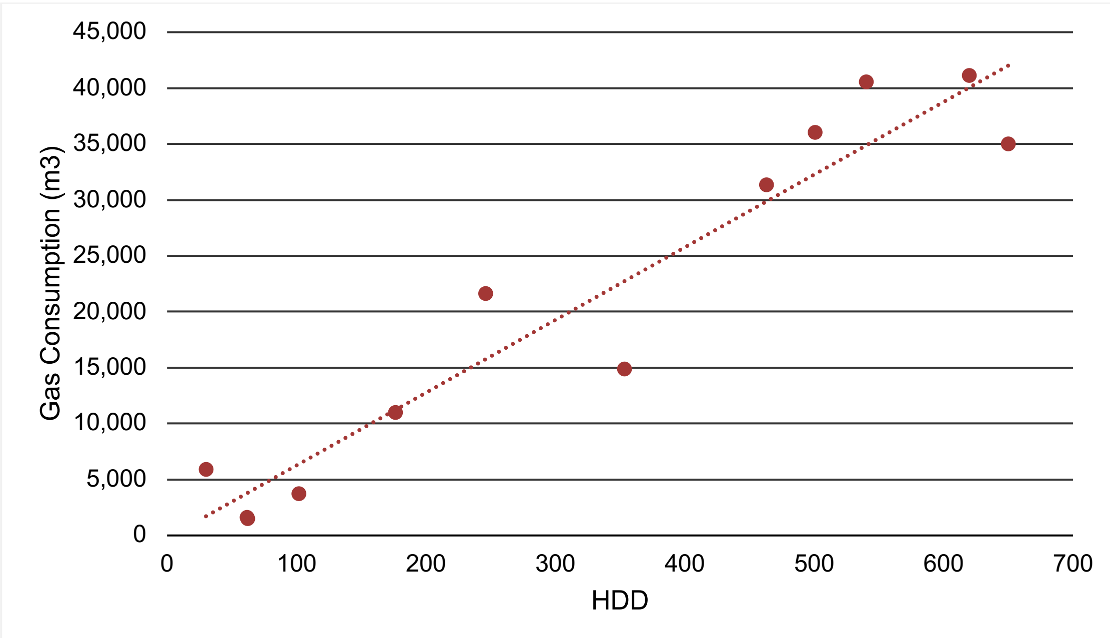


FIGURE 12: MONTHLY NATURAL GAS CONSUMPTION VERSUS HEATING DEGREE-DAYS – SCIENCE NORTH

Dynamic Earth

Annual natural gas consumption and costs are shown in Table 11. As with Science North, there is an increase in total natural gas consumption in 2022 and 2023 compared to 2021. There was a similar cost increase in natural gas since 2021 as seen with Science North. This cost escalation is continued in the analysis into the future in order to predict the utility cost savings of various ECM's involving natural gas.

TABLE 11: ANNUAL NATURAL GAS CONSUMPTION AND COSTS - DYNAMIC EARTH

Year	Natural Gas (m^3)	Natural Gas Cost Rate ($/$m^3$)	GHG Emissions (TCO_2e)
2021	29,037	$ 0.386	55.1
2022	37,225	$ 0.581	70.7
2023	49,235	$ 0.464	93.5

The natural gas consumption profiles from 2021 to 2023 are presented in Figure 13. Similar to Science North the winter months consistently see higher rates of natural gas consumption compared to summer months. This is because natural gas systems at Dynamic Earth are primarily for space heating. Therefore, it is expected that there is higher natural gas consumption in the winter months. In 2023, the monthly baseload for natural gas consumption was 673 m^3. This amount is a result of domestic water heating and service kitchen operations. The average natural gas consumption cost for 2023 is $0.464/$m^3$ ($0.045/ekWh).

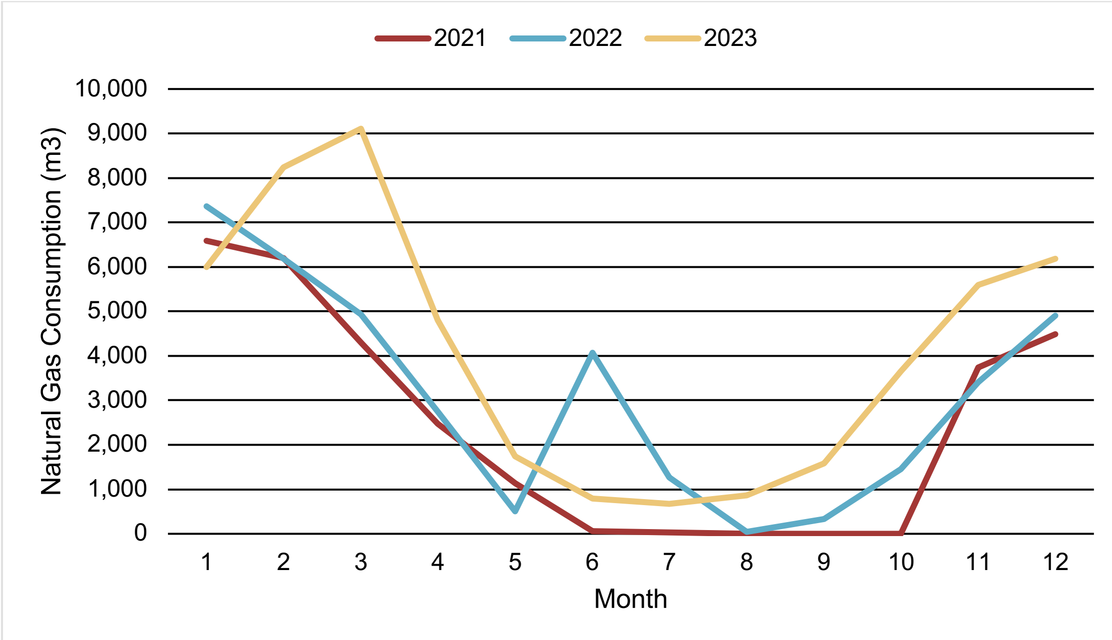


FIGURE 13: MONTHLY NATURAL GAS CONSUMPTION - DYNAMIC EARTH

A linear regression analysis was conducted in RETScreen Expert to determine the level of dependence of natural gas consumption on outdoor weather considerations. Using the Baseline Year, the linear regression model results in an R-squared value of 0.85 – indicating a strong correlation between natural gas consumption and outdoor weather. Figure 14 shows the relationship of natural gas consumption and Heating Degree-days – an indicator of outdoor weather conditions.

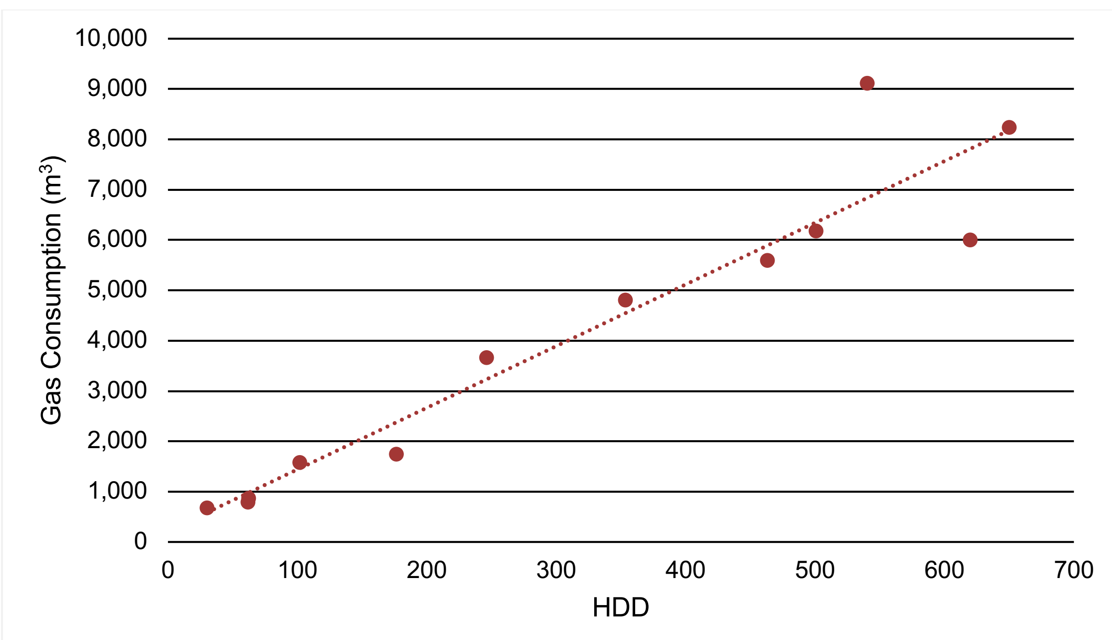


FIGURE 14: MONTHLY NATURAL GAS CONSUMPTION VERSUS HEATING DEGREE-DAYS - DYNAMIC EARTH

UTILITY RATE STRUCTURES

Specific utility rate structures were not shared with Footprint; however, total monthly costs for purchased utilities and incomes from electricity generation were shared for fiscal years 2018-19 through to 2023-24. Effective rates and escalation rates were calculated using the provided documentation. The 12-month rolling average effective cost rate for electricity purchased by Science North is shown in Figure 15 and Dynamic Earth in Figure 16. This effective rate includes the electricity purchased by Science North and the electricity sold to the grid via the solar PV array. It can be seen that there are minor fluctuations on a monthly basis and a slight increase in the average cost from 2021 to 2022 and again from 2022 to 2023. The rate of increase in electricity cost during this period was between 2-3%. This escalation rate was used to calculate utility cost savings for the ECMs. Figure 17 shows the projected increase in electricity cost rate to 2050 for both sites.

The same analysis was conducted for natural gas costs for both sites. Figure 18 shows the 12-month rolling average of natural gas cost rates for Science North. Figure 19 shows the 12-month rolling average for Dynamic Earth. As with electricity, there have been periods of increasing and decreasing cost rates. In the same period as electricity, of 2022 and 2023, there was an average cost rate increase of 68% for Science North and 33% for Dynamic Earth. This cost rate increase has largely come as a result of external global factors and the Federal Government Carbon Tax. Considering the many factors that influence natural gas prices including the recent expected cancellation of the Federal Carbon Tax, Footprint has assumed an average annual cost rate increase of 7% for natural gas. Figure 20 shows the projected increase in natural gas cost rate to 2050.

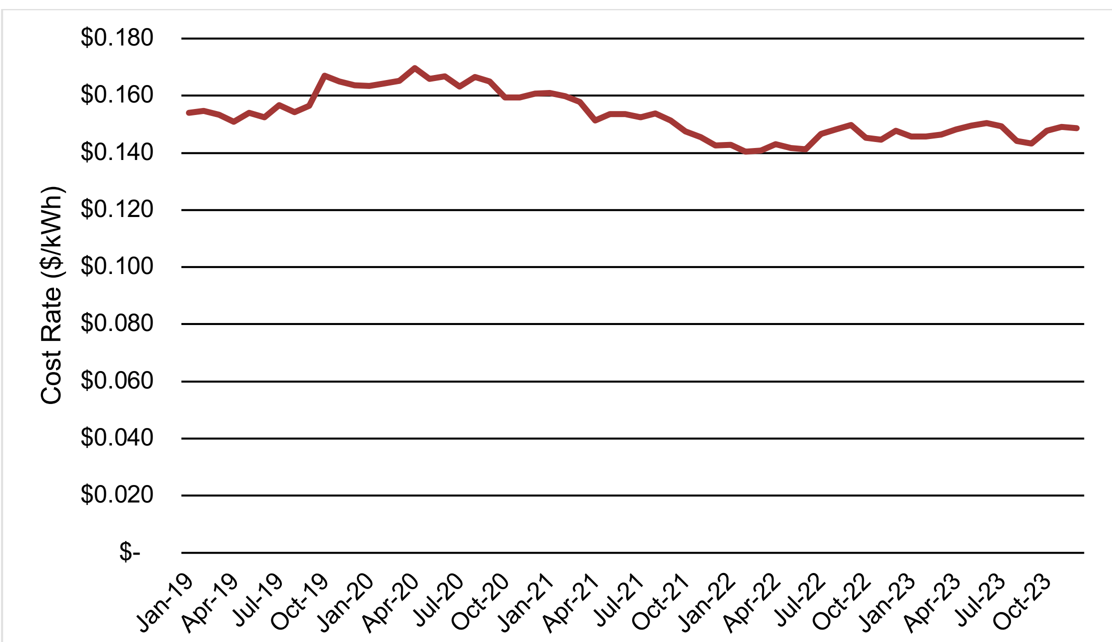


FIGURE 15: SCIENCE NORTH AVERAGE ELECTRICITY COST RATE

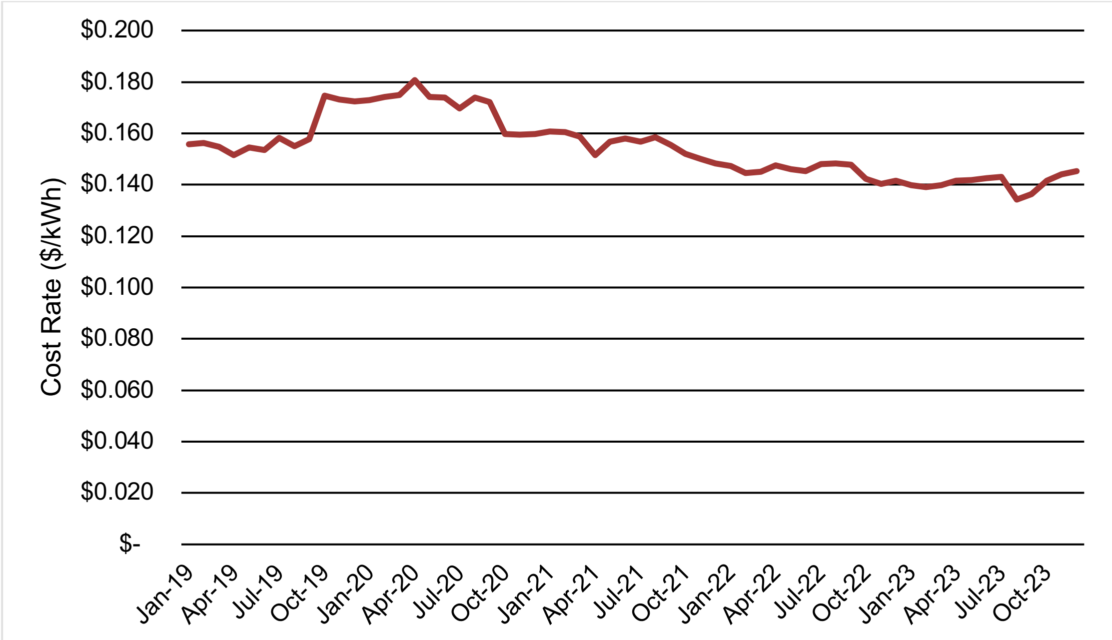


FIGURE 16: DYNAMIC EARTH AVERAGE NATURAL GAS COST RATE

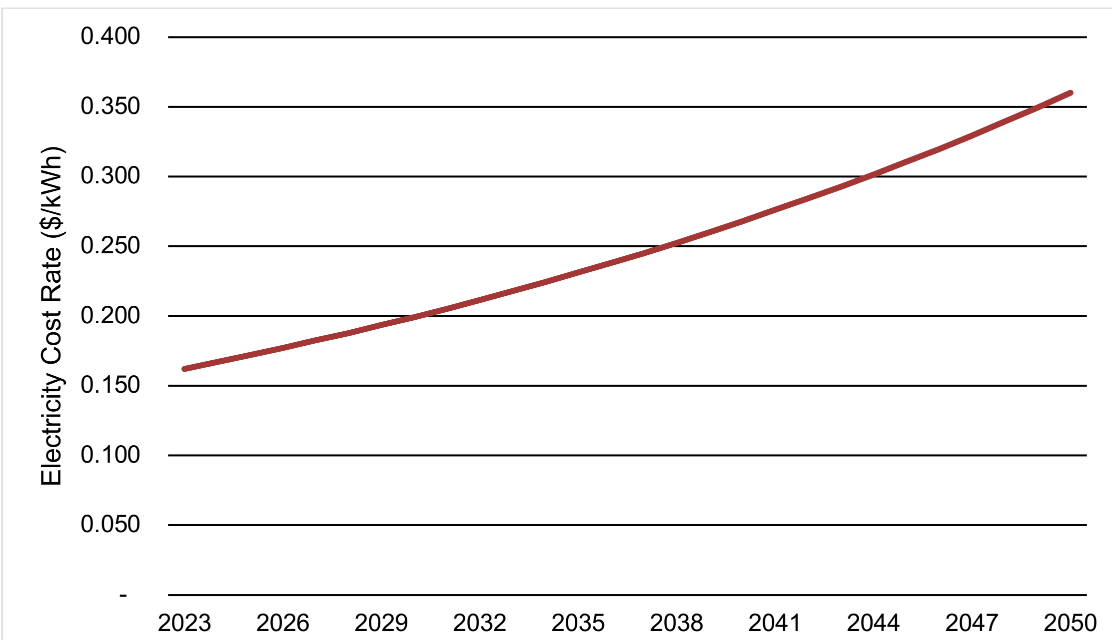


FIGURE 17: PROJECTED ELECTRICITY COST RATE

FIGURE 18: SCIENCE NORTH AVERAGE NATURAL GAS COST RATE

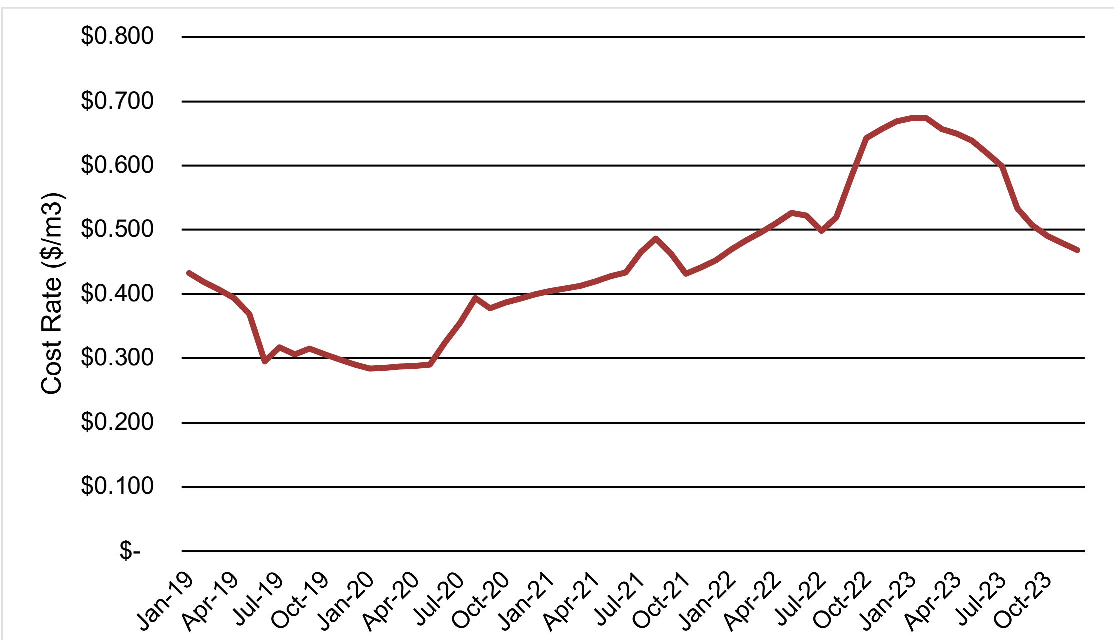


FIGURE 19: DYNAMIC EARTH AVERAGE NATURAL GAS COST RATE

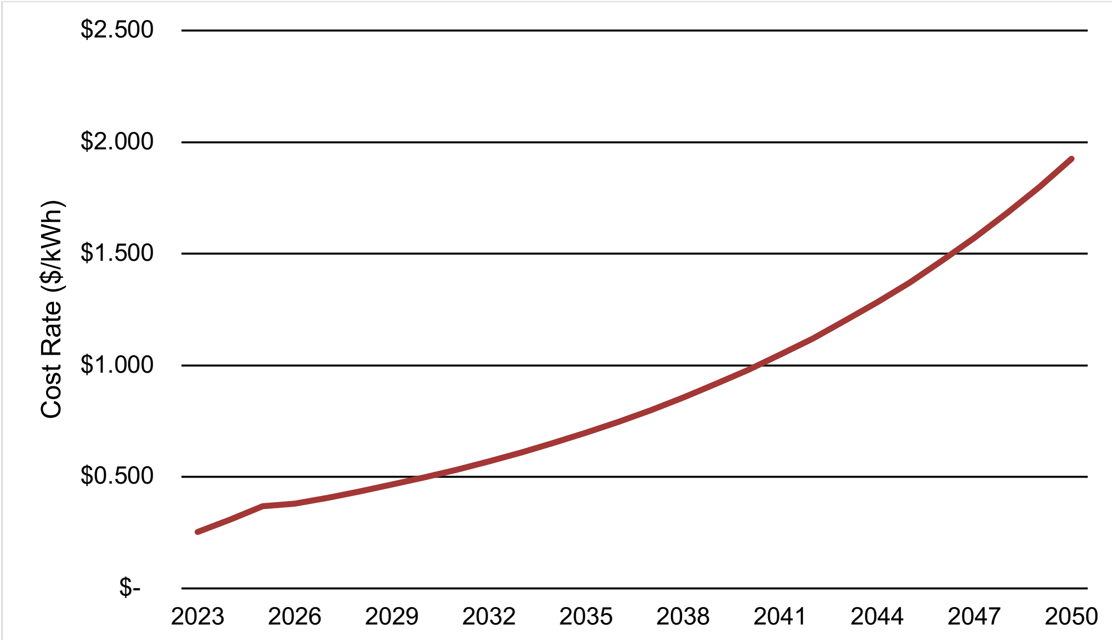


FIGURE 20: PROJECTED NATURAL GAS COST RATE

END USE BREAKDOWN

Science North

A bottom-up approach was used to calculate Science North's energy end uses. During the site visit, a review of the Building Automation System, Science North's major heating and cooling equipment, and the relationship between energy consumption and outdoor weather conditions was conducted. As a result, electricity and natural gas consumption were able to be broken down to be better understood. This also formed the basis of understanding for the amount of energy used for Science North general operations plug loads (IMAX theatre, food services, etc.). This is the amount of energy that will not be addressed by ECMs.

The end use breakdown for electricity is shown in Figure 21. The energy use for major end uses was calculated by entering the building information into RETScreen Expert. Appendix D shows the information entered into RETScreen for Science North. The majority of the electricity use is for Process Loads. This is the electricity related to general operations. In descending order following Process Loads, end uses with the largest representation of the total electricity consumption includes: Fans, Lighting, Pumping, Cooling, and Domestic Water Heating. The GHG emissions associated with each of these end uses is listed in Table 12. While the emissions associated with each end use will need to be addressed to achieve Net Zero Carbon, the vast majority of GHG emissions are a result of natural gas consumption.

Natural gas consumption at Science North can largely be broken down into two end uses: space heating and domestic hot water heating. As expected, the vast majority of the natural gas consumed by Science North is for space heating at 95%. As a result, the majority of the GHG emissions of Science North is from natural gas-fired space heating equipment. To achieve Net Zero Carbon by 2050, it is crucial for the natural gas space heating equipment to be addressed.

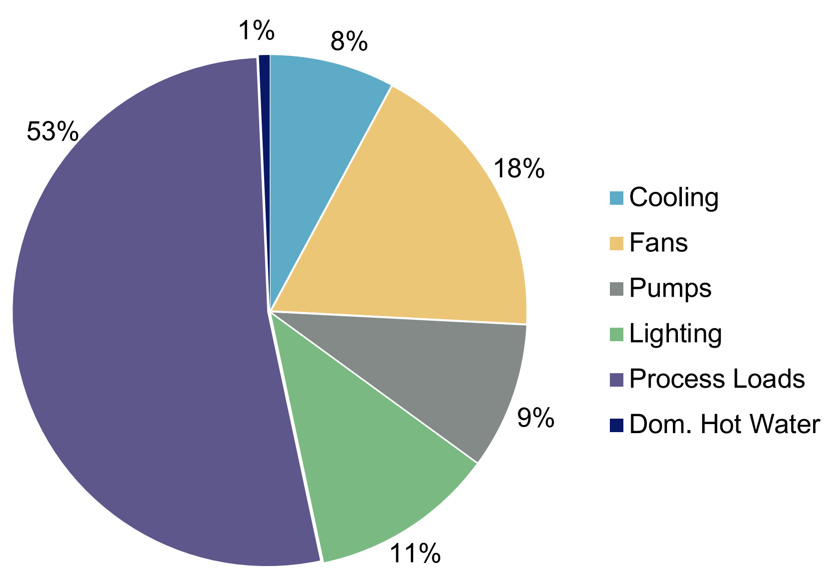


FIGURE 21: ELECTRICITY END USE BREAKDOWN – SCIENCE NORTH

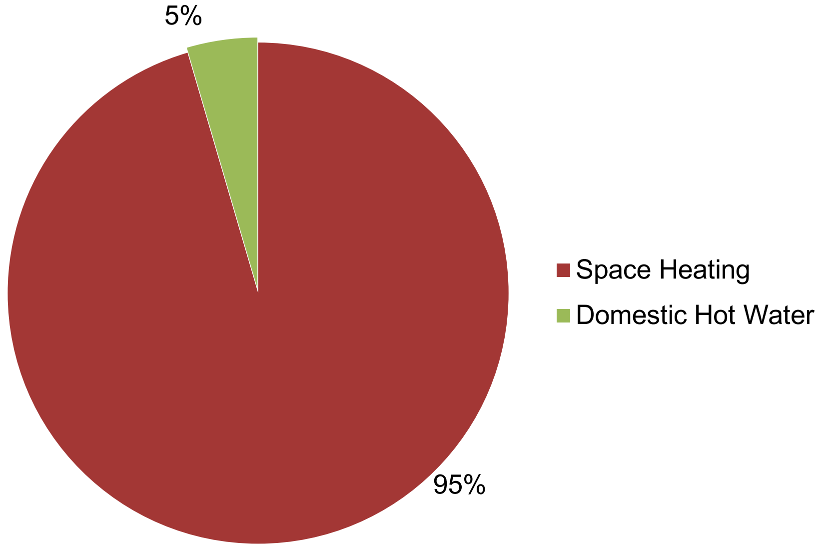


FIGURE 22: NATURAL GAS END USE BREAKDOWN – SCIENCE NORTH

TABLE 12: SCIENCE NORTH END USE BREAKDOWN

	End Use	Energy (ekWh)	GHG Emissions (kg CO_2e)
Electricity	Space Cooling	133,889	3,523
	Fans	336,184	8,059
	Pumps	172,146	4,136
	Lighting	218,333	5,218
	Process Loads	988,056	23,618
	Dom. Hot Water	12,919	306
Natural Gas	Space Heating	2,505,278	443,385
	Dom. Hot Water	115,137	21,125

The primary difference between energy consumption and GHG emissions proportions for the end uses is a result of the emissions factor differences between electricity and natural gas consumption. For Science North, only 57% of the total energy consumption is from natural gas, but this represents 91% of the total emissions. Therefore, it is important to target natural gas consumption as part of the pathway to Net Zero Carbon as it contributes more towards emissions compared to electricity consumption.

Figure 23 below highlights the difference in how energy consumption and overall GHG emissions compare at Science North, with natural gas contributing significantly more to the site's GHG emissions compared to the energy consumed. It also demonstrates that there is no viable path to Net Zero Carbon without addressing natural gas consumption.

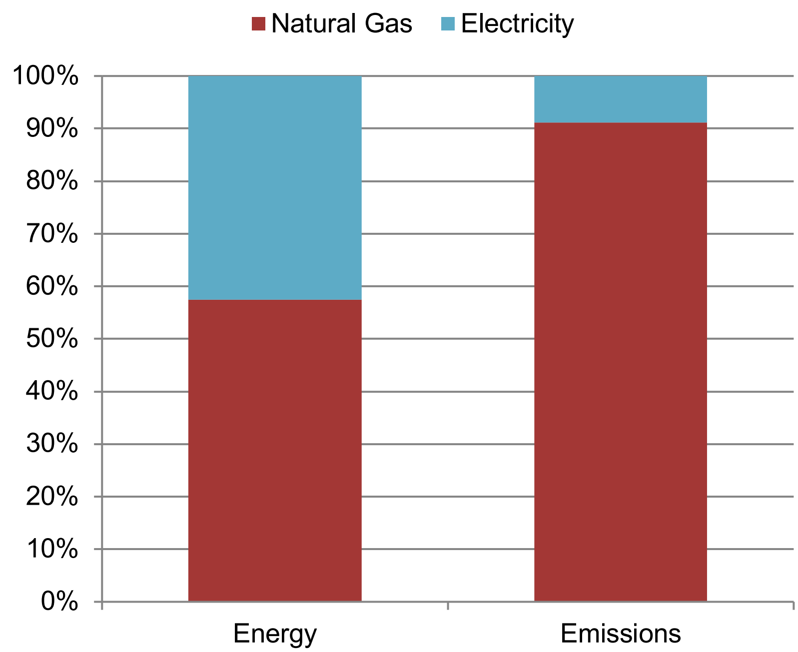


FIGURE 23: 2023 ENERGY AND GREENHOUSE GAS COMPARISON – SCIENCE NORTH

Dynamic Earth

Similar to Science North, a bottom-up approach was used to calculate Dynamic Earth's energy end-uses. During the site visit and the review of the equipment use schedules, Dynamic Earth's major mechanical equipment, and the relationship between energy consumption and outdoor weather conditions. As a result, electricity and natural gas consumption on site were able to be broken down to be better understood.

The end use breakdown for electricity is shown in Figure 24. The energy use for major end uses was calculated by entering the building information into RETScreen Expert. Appendix D shows the information entered into RETScreen for Dynamic Earth. The majority of the electricity use is for Process Loads. This is the electricity related to general operations. In descending order following Process Loads, end uses with the largest representation of the total electricity consumption includes: Fans, Lighting, Cooling, and Pumping. The GHG emissions associated with each of these end uses is listed in Table 13. The Fan energy is the energy associated with the operation of the rooftop unit fans. While the emissions associated with each end use will need to be addressed to achieve Net Zero Carbon, the vast majority of GHG emissions are as a result of natural gas consumption.

Natural gas consumption at Dynamic Earth can largely be broken down into two end uses, space heating and domestic hot water heating. As expected, the vast majority of the natural gas consumed by Dynamic Earth is for space heating. 96% of the natural gas consumption at Dynamic Earth is for space heating. As a result, the majority of the GHG emissions of Dynamic Earth is from natural gas-fired space heating equipment. Therefore, in order to achieve Net Zero Carbon by 2050, natural gas space heating equipment will need to be addressed.

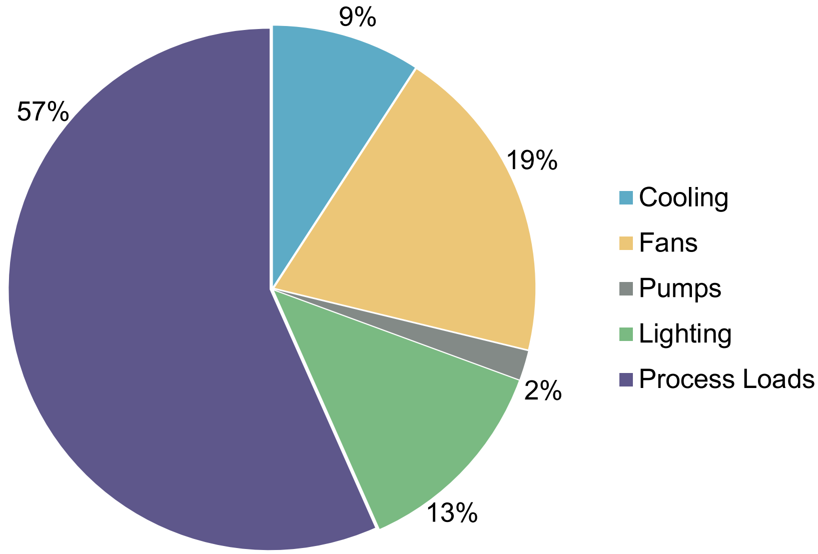


FIGURE 24: ELECTRICITY END-USE BREAKDOWN - DYNAMIC EARTH

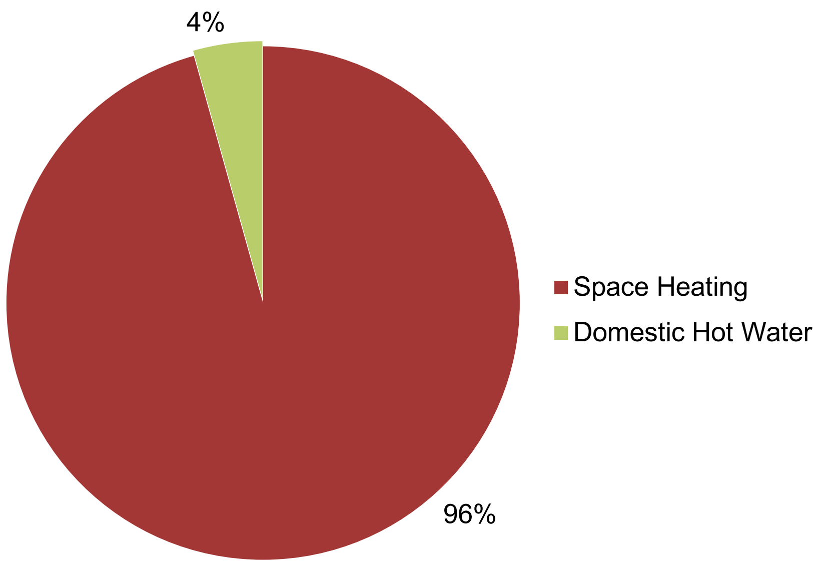


FIGURE 25: NATURAL GAS END-USE BREAKDOWN - DYNAMIC EARTH

TABLE 13: DYNAMIC EARTH END USE BREAKDOWN

	End Use	Energy (ekWh)	GHG Emissions (kg CO_{2e})
Electricity	Space Cooling	29,964	716
	Fans	64,195	1,534
	Pumps	5,923	142
	Lighting	41,731	997
	Process Loads	185,208	4,426
Natural Gas	Space Heating	487,412	89,430
	Dom. Hot Water	22,165	4,067

Much like Science North, Dynamic Earth's natural gas consumption also contributes more towards GHG emissions compared to total energy. For Dynamic Earth, only 61% of the total energy consumption is from natural gas, but this represents 92% of the total emissions. Figure 26 below highlights the difference in how energy consumption and overall GHG emissions compare at Dynamic Earth, with natural gas contributing more to Dynamic Earth's GHG emissions compared to the energy consumed. It also demonstrates that there is no viable path to Net Zero Carbon for Dynamic Earth without addressing natural gas consumption.

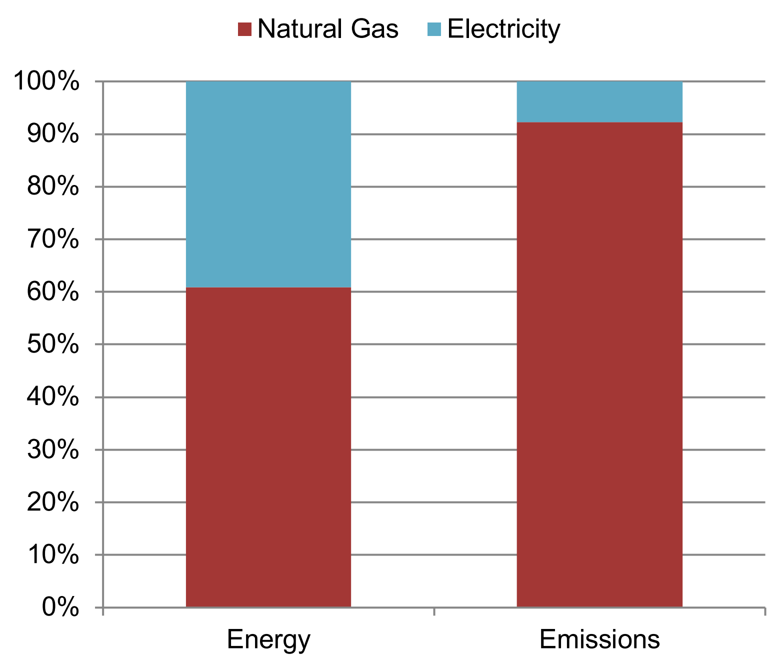


FIGURE 26: 2023 ENERGY AND GREENHOUSE GAS COMPARISON – DYNAMIC EARTH

Scenario Analysis

As part of the Government of Canada's Net Zero Challenge, Footprint developed future scenarios to better understand the potential conditions and changes between the Baseline Year and 2050. The development of these scenarios was guided by three key principles: plausibility, consistency, and responsibility.

The principle of plausibility was achieved by utilizing credible sources of information to construct a plausible narrative of future conditions. Ensuring consistency in the internal logic of the future scenario was crucial, as assumptions that deviate from current trends and evidence can lead to unrealistic outcomes.

Finally, the responsibility principle was upheld by maintaining an objective approach, without regard for the preferences of Science North. The scenarios were developed irrespective of whether the future conditions would favour Science North's ability to achieve Net Zero Carbon.

This rigorous and impartial approach to scenario development provides a robust foundation for understanding the potential challenges and opportunities that may arise in the pursuit of net zero carbon emissions by 2050. The Scenario Analysis is based on assumptions in four primary contexts: policy and regulations, socio-economics, infrastructure, and technology.

Regarding policy, the scenario has removed the Federal Carbon Tax costs for natural gas consumption effective from 2026. Natural gas costs will continue to see an increase in overall average costs as described in the previous section. However, a higher cost escalation rate for natural gas has been assumed for a variety of reasons including recent significant escalation in costs, assumed increases in extraction and distribution costs in the future, and possible re-establishment of carbon taxing by some other means in the future. It has also been assumed that the availability of offset purchasing in 2050 will continue to exist as it does today. As decarbonization becomes more popular, it is anticipated that the carbon market will likewise grow with more options for purchased offsets to become available in the future.

As part of socio-economic factors, Footprint has included in the analysis a factor for construction cost escalation into the future. Some measures are not expected to be implemented for over 10 years. As such, today's costs for equipment and construction will escalate when the time comes to implement those measures. Providing a more accurate implementation cost in this Plan helps Science North better prepare its Capital Plans to include the cost escalation. Footprint has also received information regarding the future expansions of both facilities – either in concept or plans. This anticipation of facility growth helps to understand the future conditions of both sites and allows for the change in expected energy consumption as a result of the expansions. The energy consumed in the expanded areas is included in the calculations for Net Zero Carbon. Footprint has also used the existing Capital Plans and the expected remaining lifespan of equipment to create the implementation timeline to achieve Net Zero Carbon. While it is advantageous to implement decarbonizing measures as early as possible, Footprint recognizes the realities of economics and achieving the highest return on investment for mechanical equipment.

Assumptions regarding available infrastructure are critical in developing the future emissions scenario. Footprint has used Environment and Climate Change Canada's most recently published expected electricity grid emissions for Ontario to calculate the emissions related to electricity consumption between 2025 and 2050. GHG emissions from electricity consumption and electrification of specific systems are dependent on the year analyzed. In order to provide a realistic future scenario, Footprint has assumed that there are no significant developments in improved utility infrastructure such as the availability of hydrogen for clean energy consumption. The Plan has been developed using only available infrastructure.

While it can reasonably be assumed that the future state of technology may bring innovations currently unfathomed, the Plan has been developed using technologies that are currently available and have proven successful case studies in the real world. While there may be a technology that becomes available between now and 2050, only currently available mechanical equipment has been used to develop the Plan. Furthermore, using the recent rapid development of air-source heat pump technology, one can reasonably assume improvements in overall efficiency and operating temperatures to continue into the future. For the purposes of this Plan, the operating temperatures, ambient temperature limitations, and efficiencies of technology currently available is assumed regardless of the implementation year in this Plan. This provides a conservative estimation for performance in the future for heat pump technologies. The same has been assumed regarding solar PV technology. The amount of energy generated currently on site has been normalized based on PV array area to predict the future generation potential regardless of any anticipated breakthrough in solar PV efficiency.

Finally, Footprint has also included the anticipated impact of climate change on the energy consumption of both facilities. Annual Heating Degree-days between 2024-2050 have been assumed for Sudbury based on the Representative Concentration Pathway (RCP) 4.5 emissions scenario. This assumes a global peak in GHG emissions in 2040 and an average increase in global temperatures between 2°C and 3°C by 2100. The effect of this change is used to calculate the expected change in heating and cooling loads for both facilities going into the future. Future Heating Degree-days was provided by the Climate Atlas of Canada and was developed by the University of Winnipeg with support from Environment and Climate Change Canada among other governmental partners.

Mitigation strategies to manage the future scenario have also been developed. The Plan has been developed in such a way that each measure is implemented as early as possible. This avoids possible emissions from delaying projects until later than necessary. Working within the limitations of the existing equipment replacement cycles, the measures recommended in both sites' pathways are assumed to be done as early as possible. This is the driving principle behind the Quick Wins which are all to be implemented in the next five years.

The solutions also all primarily focus of reducing GHG emissions – either through improved efficiency or through fuel-switching. In Ontario, the electricity grid is nearly carbon-free – meaning the replacement of natural gas equipment for electric can significantly reduce the emissions related to the operation of that system. This has been a guiding principle in the development of the Net Zero Carbon Plan.

BUSINESS-AS-USUAL CASE

In order to forecast Science North's emissions out to the year 2050, a "Business-as-Usual" (BAU) scenario was developed. Figure 27 and Figure 28 illustrate the magnitude of GHG emissions in the case where no emissions reduction measures are implemented at Science North and Dynamic Earth, respectively. The BAU scenario accounts for planned increases in floor area through future projects, and an increase in average temperatures based on changing climate. It is forecasted that in the next 25 years, the annual Heating Degree-days are anticipated to decrease by 4%[6].

The BAU scenario for Science North (Figure 27) anticipates a decrease in GHG emissions of 5% by 2050. For Dynamic Earth (Figure 28), there is an expected increase of 1%. The variation in emissions is a result of the changes expected to Ontario's electricity grid and anticipated additions to the buildings described in the Building Description sections.

[6] The Climate Atlas of Canada: https://climateatlas.ca/map/canada

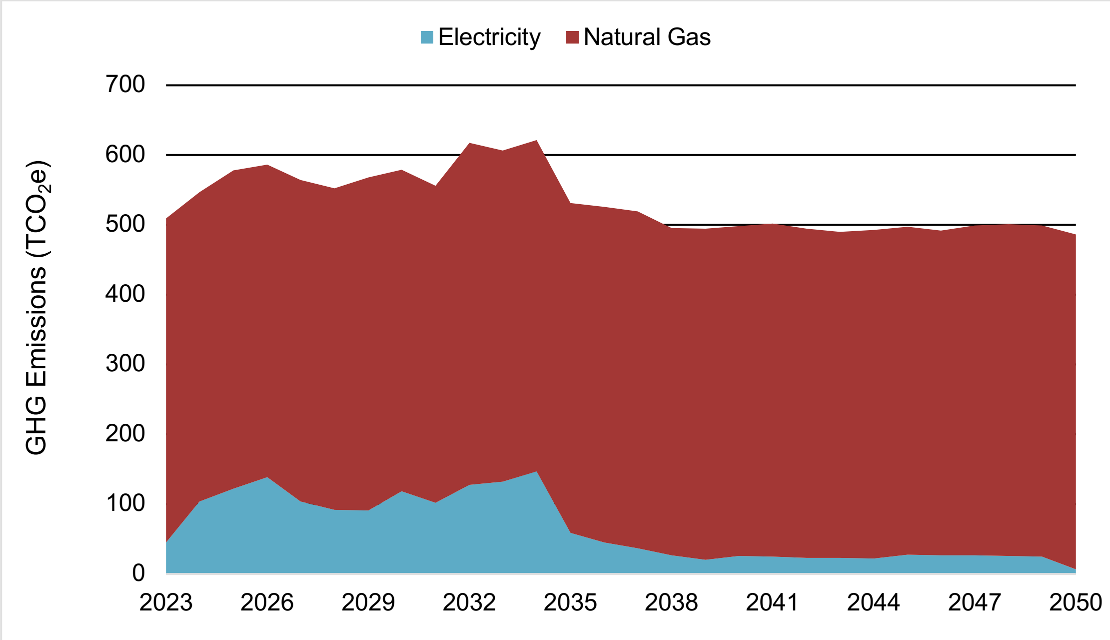


FIGURE 27: BUSINESS-AS-USUAL EMISSIONS FORECAST – SCIENCE NORTH

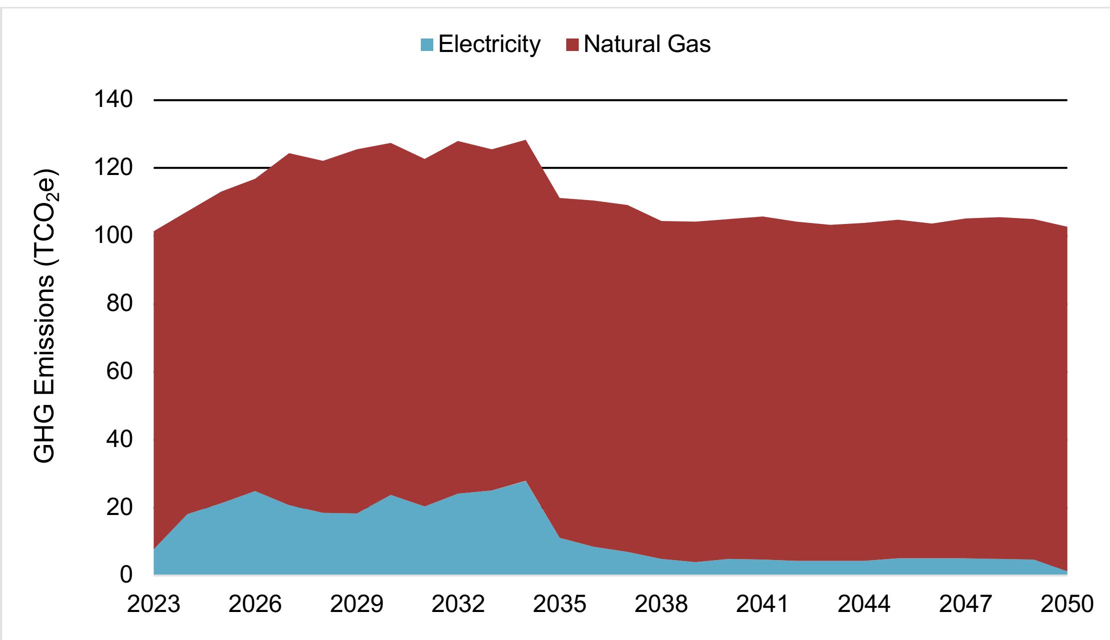


FIGURE 28: BUSINESS-AS-USUAL EMISSIONS FORECAST - DYNAMIC EARTH

Energy Conservation Measures – Science North

The focus of the measures in this Plan are energy and greenhouse gas reductions. As such, the energy conservation measures target load reduction, fuel switching, and renewable energy.

- Load reduction: improved envelope performance, controls improvements, higher efficiency mechanical equipment
- Fuel switching: replace natural gas systems with electric alternatives
- Renewable energy

Carbon reduction measures typically have long or negative payback periods due to current and future utility rates. The utility cost escalation rates used were described in the previous section. GHG Emissions savings for each measure change based on the implementation year due to the fluctuating GHG emission factors. The expected change in emissions factor over time is shown in Figure 6 in the Historical Utility Data section. GHG percent reduction compares the GHG savings based on the aforementioned factors with the total emissions of the Baseline Year of 2023. The economic analyses are calculated for the whole solutions of each ECM rather than on a per unit replacement basis.

QUICK WINS

Replace Pneumatic Damper Controls & Install Carbon Dioxide Sensors

During the site review, it was noted that certain air-handling units use pneumatic actuators to control the return air and outdoor air dampers. Replacing these pneumatically controlled dampers with electronic dampers will improve the overall control of the position of the dampers. Replacing these controllers will also enable the removal of the air compressors from the site. These compressors generally run every 10 minutes; however, the compressed air line in the Large Snowflake has a leak requiring additional running of the compressor. The air-handling units that currently operate using pneumatic damper controls include: AC-1, AC-2, AC-3, AC-4, AC-5, and AC-6.

The second part of this measure is the installation of carbon dioxide sensors in the return air streams. In the air-handling units that already have these sensors, the outdoor air dampers are automatically controlled to only provide the amount of ventilation air required based on the level of occupancy in the spaces that those air-handling units serve. This demand control ventilation is currently implemented in the air-handling units that have carbon dioxide sensors. This part of the measure involves the installation of carbon dioxide sensors in the remaining air-handling units and adjusting the controls to respond to the concentration of carbon dioxide in the return air stream – a proxy for the level of occupancy in the space. Air-handling units that currently do not have carbon dioxide sensors in the return air stream include: AC-12, AC-13, AC-14, AC-15, and AC-16.

This measure is expected to have a minimal level of effort. The majority of air-handling units at Science North already use electronic damper controllers. This measure describes the replacement of the remaining pneumatic damper controls with electronic damper controllers. The new controllers will need to be connected to the BAS to improve the controls of the air handlers. The addition of carbon dioxide sensors in the listed air handlers will require a connection to the BAS to respond to carbon dioxide levels in the return air stream.

There are expected to be small impacts to operations during the installation at each air-handling unit. Each air handler should be down for only a few hours for the installation of controllers and sensors, connection to the BAS, and programming of the BAS.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2027	13,979	20,774	648	$427,000	$70,000

Occupancy and Daylight Sensors

Science North recently replaced the vast majority of the lighting to LED. At the time of the site review, approximately 99% of the lighting had been upgraded. The time of day controls on the lighting are also set to reflect the actual patterns of building occupancy, accounting for factors such as the operations staff and cleaning staff using the building outside of opening hours. Therefore, the only remaining opportunities to reduce the lighting load at Science North will be through the installation of daylight and occupancy sensors. Installing these sensors in strategic areas of intermittent occupancy and near windows can further reduce the electricity consumed by lighting.

The areas that are good candidates for the installation of occupancy sensors include the offices and meeting rooms in the Entrance Building, the second floor of the Small Snowflake, and the meeting rooms in the Large Snowflake. For daylight sensors, the ideal areas include the lobby of the Entrance Building, the second floor of the Small Snowflake, and the areas adjacent to the window wall of the Large Snowflake.

The level of effort expected for this measure is minimal. It is expected that the sensors are installed and connected to the lighting controls in a minimal amount of time in each area. There will be little impact to the operations of the building. The areas where an installation is occurring will need to be vacant for the time of installation. Ideally, this measure can be completed during a regular scheduled shutdown of the science centre much like the week-long shutdown that occurred during the site visit.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2027	0	12,060	8	$65,900	$31,300

Variable Speed Drives

At the time of the site visit, the majority of the fan motors had variable speed drives. The only fans that were noted to not have variable speed drives were air-handling units AC-2 and AC-3. This measure involved installing variable speed drives for these remaining fan motors and programming the operation to vary the speed of the fans based on the demand in the spaces they serve. It is assumed that the existing fan motors are incompatible with variable speed drives and therefore will also need to be replaced.

This measure is not expected to require a significant amount of effort or time commitment to implement and achieve energy savings. It is also expected to have a minimal impact on operations. After the variable speed drives and new fan motors are installed and adjustments to the BAS sequences of operations are made, the fan energy demand is expected to decrease. It is expected that there will be little to no additional work required from the building operations team.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2027	0	37,207	24	$203,400	$16,250

Convert Domestic Water Heaters to Heat Pumps

The primary domestic hot water heater at Science North is a natural gas-fired heater and storage tank. There is an opportunity to convert this system from natural gas to electric by installing a heat pump domestic water heater. These air-source heat pump systems are commercially available in standard sizes and are offered at a minimal cost premium compared to a like-for-like replacement.

According to the *Lifecycle Asset Condition Report* conducted by Infrastructure Ontario in 2020, the domestic water heater is at the end of its expected life and can be replaced any time.

This measure is expected to require a minimal level of effort. It involves a relatively simple changeout of the existing equipment with an electrified system. This measure is also expected to have a minimal impact on operations. Following a quick pause in service to replace the water heater, there is expected to be no additional work required from the building operations team.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2027	10,053	-42,017	446	$5,690	$56,250

Air-Source Heat Pump Packaged Rooftop Units

Science North currently operates packaged rooftop heating and cooling ventilation units to provide conditioned air, located on the roof of the Entrance Building near the cooling tower. Known as AC-9 and AC-10, the existing units use natural gas-fired furnaces to provide heating. There is an opportunity to electrify these systems by replacing these units with air-source heat pump packaged rooftop units. These units are readily available in standardized sizes and are equipped with either a natural gas-fired furnace or an electric resistance heater as the supplemental heating source. The outdoor temperature at which the change from the heat pump to the supplemental source varies between manufacturers. For this analysis, the changeover temperature was set at -12°C. It was assumed that the supplemental heating source is electric resistance. According to the *Lifecycle Asset Condition Report* conducted by Infrastructure Ontario, the existing rooftop units are end-of-life. It is recommended that these rooftop units are replaced with heat pump units to avoid another lifecycle with natural gas-fired units.

The level of effort expected for this measure is not much higher than a like-for-like replacement of the rooftop units. There will be additional effort required for capping off the existing gas lines if a unit with an electric resistance supplemental heating system is installed. There is expected to be little to no significant impact to operations during the equipment replacement. Additional monitoring and maintenance may be required to ensure the systems are operating as intended, but the changes should not be significantly different from the existing systems.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2027	11,155	-70,000	479	($121,450)	$483,750

Quick Win Summary

The implementation of these measures will result in decreases of annual GHG emissions. Figure 29 below shows the expected decrease in emissions compared to the BAU scenario over time. In 2050, it is expected that the Quick Win measures will be responsible for a 16% reduction in GHG emissions.

Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction vs BAU	Utility Cost Savings (2025-2050)	Total Capital Cost
35,187	-41,977	479	11%	$580,540	$657,500

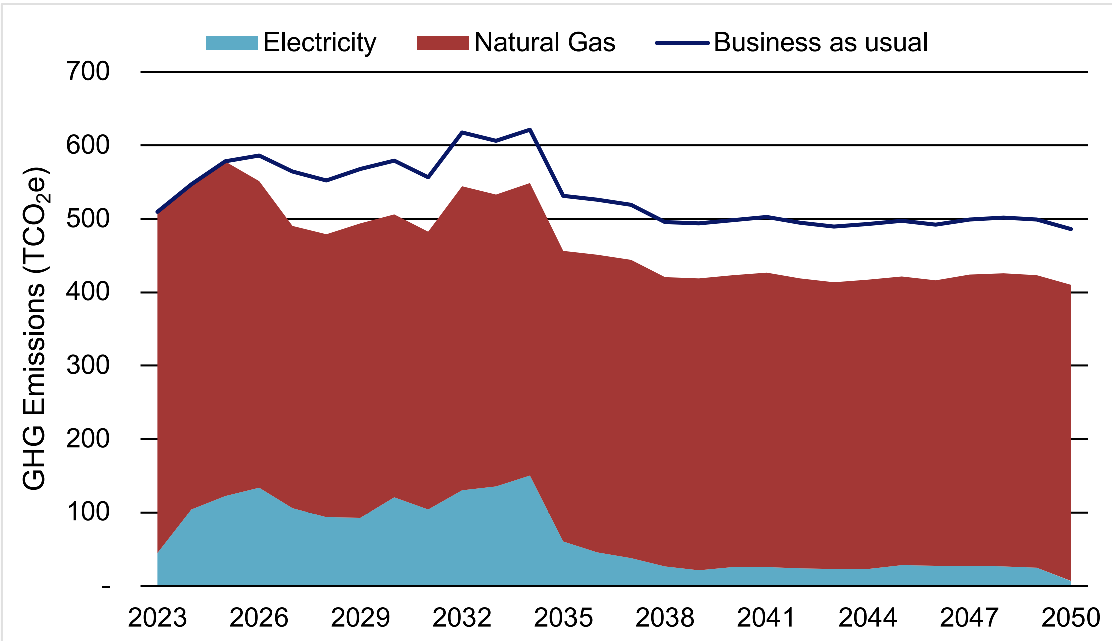


FIGURE 29: EXPECTED GHG REDUCTION THROUGH QUICK WINS – SCIENCE NORTH

DEEP RETROFIT MEASURES

Alongside the Quick Win opportunities, there are a number of large capital measures that will have a significant impact on GHG emissions at Science North. As a result of their added complexity, these Deep Retrofit measures require more significant planning and design compared to the Quick Win measures. The Deep Retrofit measures are a combination of planned significant upgrades and measures that are to be implemented in the future.

Window Wall Replacement

During the investigation, it was noted that there are plans for an extensive replacement of the windows at Science North. The procurement process has already been initiated and the window replacements are set to begin in 2026. The majority of the windows are original to the building and are well beyond their effective life. This measure was also identified in an ASHRAE Level I energy and water audit conducted in 2021.

The entire window replacement is expected to require a significant level of effort and disruption during the construction period. There will need to be coordination between the construction team and the building's operations to determine the ideal timing of the window retrofits. The expected implementation year of 2026 is when the energy and GHG savings are expected to take effect. While the energy and GHG savings from this measure are not significant, this measure is critical to lowering the overall energy demand of the science centre. Regardless of savings, the windows require replacement since they are no longer performing as originally intended.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2026	4,391	58,000	253	$420,688	$2,000,000

Lake Water Cooling Heat Exchanger

Science North is located directly adjacent to Ramsey Lake. As such, there is an opportunity to take advantage of this location to provide a free source of cooling energy. This measure involves installing a closed glycol loop connecting the science centre's cooling system to a heat exchanger submerged in a lake. The heat exchanger will use the cool lake water to cool the glycol that is returning to the science centre to be used for space cooling. This system will negate the chiller operation, thus reducing electricity consumption. The viability of this measure is dependent on three factors:

- The lake water temperatures required to satisfy the peak cooling load of the facility in the summer
- The location of the target lake water temperatures in Ramsey Lake in relation to Science North
- The compatibility of the existing Science North cooling system with the proposed new cooling infrastructure (i.e. glycol loop and heat exchanger)

The first step to determine the viability of this measure is to understand the temperature profile of Ramsey Lake. The deeper underwater that a heat exchanger can be installed, the more stable the temperatures will be during the summer months. As the lake water temperature warms during the summer, the water near the surface will increase in overall temperature. This is due to a phenomenon known as stratification. Warmer water is less dense than colder water; therefore, as the top layers of water are warmed by the sun, the lower density water effectively "floats" on the colder layers below. As a result, deeper waters will have more stable temperatures year-round. A temperature profile study was conducted for Ramsey Lake measuring temperatures at various depths in 1989 – a more recent study is not available. At a depth of 18 metres, the water temperature during summer is consistently approximately 8°C. Figure 30 shows the temperature profile of Ramsey Lake at various depths throughout the summer months. This temperature is ideal to provide cooling energy for the building.

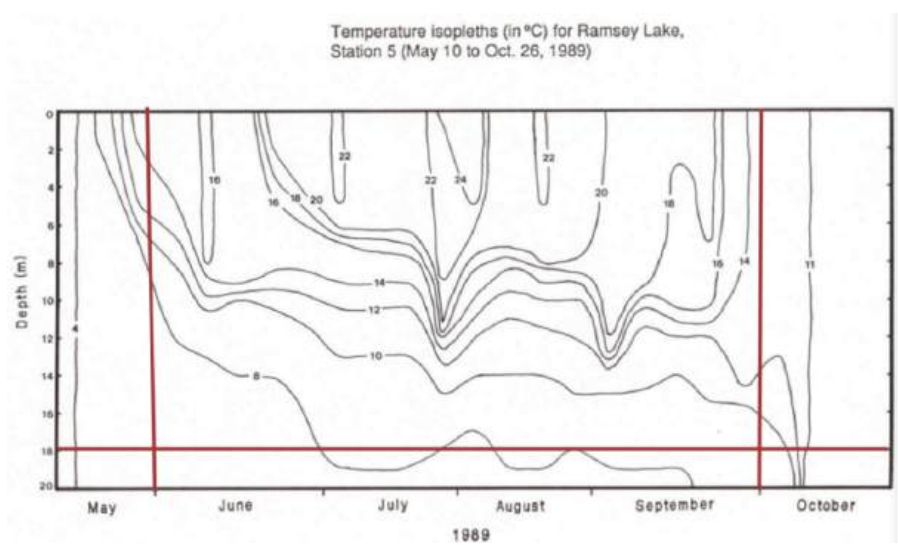


FIGURE 30: WATER TEMPERAUTRES AT VARIOUS DEPTHS FOR RAMSEY LAKE

The depth of Ramsey Lake is not distributed evenly. Based on the location of Science North, Ramsey Lake achieves this ideal depth at a distance of 0.17 nautical miles (about 315 metres) away from the shore. This is the distance away from the shore where the heat exchanger will need to be placed to achieve the ideal water temperature.

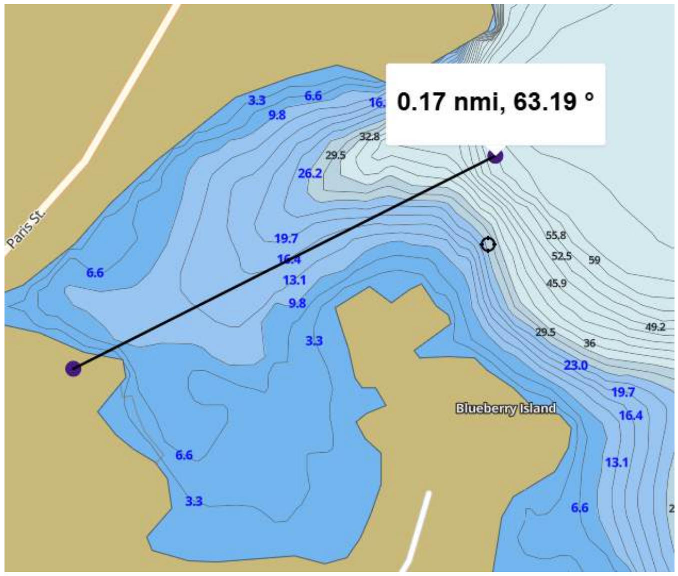


FIGURE 31: TOPOGRAPHICAL MAP OF RAMSEY LAKE NEAR SCIENCE NORTH SHORE

The final consideration for this measure is the location and distribution of the existing cooling infrastructure. At Science North, the chiller and cooling tower are located at the west end of the Entrance Building – the furthest possible point from Ramsey Lake. If the source of cooling is to be Ramsey Lake, it would be impractical to install glycol piping from the existing chilled water plant to and from the lake. It would equally be impractical to relocate the entire chilled water system and rework the internal piping infrastructure to be closer to the lake.

There is an opportunity to take advantage of the planned expansion of the Lobby and Link areas to install a new mechanical room to house this solution. The new mechanical room can be located on the northern wall of the Small Snowflake. The planned renovations around the Small Snowflake include a reworking of the eating area. This new mechanical room would be located adjacent to the eating area. As a result, the space could be designed in such a way that the internal heat exchanger, distribution pumps, and distribution piping could be on public display. The existing infrastructure is set up to provide chilled water from the Entrance Building to the Small and Large Snowflakes. Following the installation of the Lake Water Cooling Heat Exchanger, the chilled water pipes serving the Small and Large Snowflakes from the Entrance Building will be cut and capped off. The cooling energy from the lake will supply only the Small and Large Snowflakes. The Entrance Building will remain on the existing chilled water network.

The displaying of the inner workings of this measure will serve as a learning opportunity for the visiting public. It will showcase the inner workings of the system while being an example of sustainability in the science centre. The display would demonstrate how the natural world can be sustainably used to benefit the science centre while also displaying the engineering systems involved with providing cooling energy.

The proposed system location is presented in Figure 32.

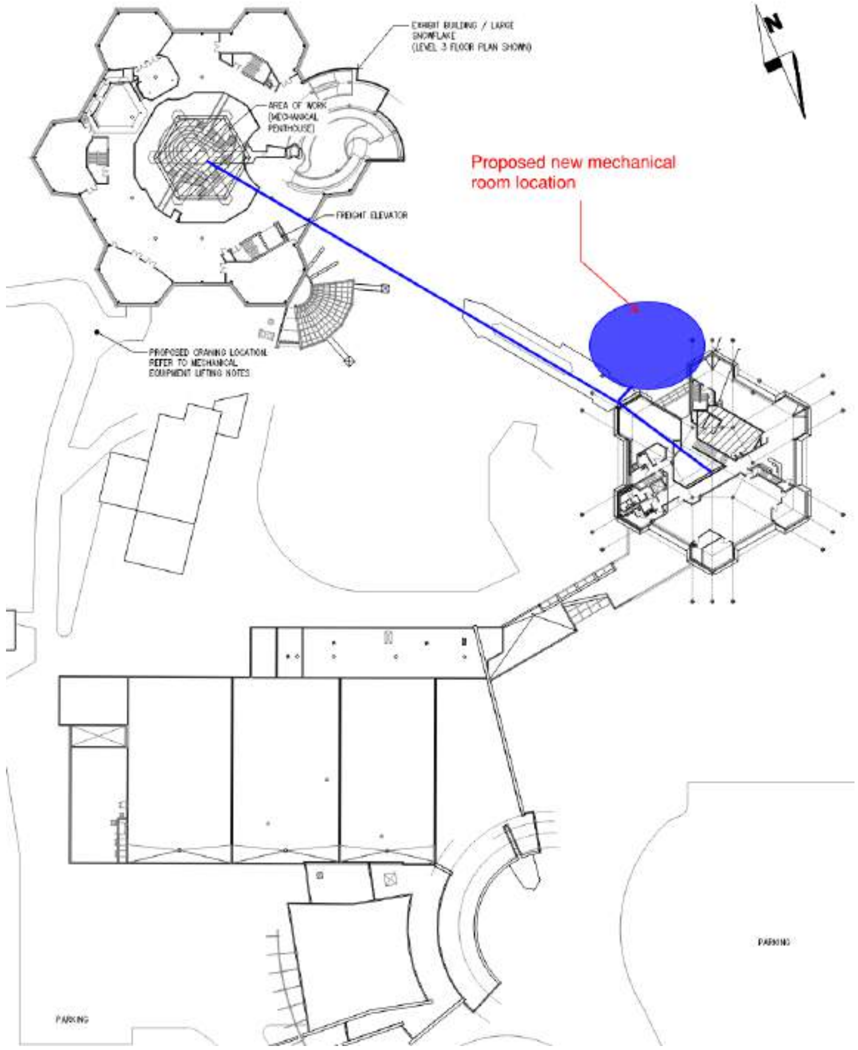


FIGURE 32: PROPOSED NEW CHILLED WATER DISTRIBUTION

Several equipment installations are required for this measure:

- Glycol-to-water heat exchanger in Ramsey Lake
- Glycol pipes to and from the heat exchanger
- New mechanical room and associated pumps
- Glycol-to-water heat exchanger in the new mechanical room
- New pumps and pipes connecting the chilled water to the existing network

The costs associated with this measure do not include the cost of constructing the new mechanical room. The new mechanical room cost is included in the Water-Source Heat Pump measure.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2032	0	74,696	29	$337,300	$800,000

Water-Source Heat Pump

There is an opportunity to use the stable temperatures of the lake described previously as the heat source for a water-source heat pump. A water-source heat pump uses the year-round heat energy in a body of water as the source of building heating in the winter and a heat sink for heat rejection (i.e., cooling) during the summer months. As explained in the Lake Water Cooling Heat Exchanger, the stable year-round water temperatures enable a water-source heat pump to be a viable option.

For this measure, a heat exchanger will be located in the same location and nearby to the Lake Water Cooling Heat Exchanger at a depth of 18 metres and a distance of 315 metres from the shore. This area of the lake will provide ideal water temperatures for efficient operation of the water-source heat pump. This measure takes advantage of the proposed Lobby and Link expansion for the construction of a new mechanical room to house the water-source heat pump along with the associated pumps and piping. The water-source heat pump is assumed to have a heating capacity of 200 tons to meet the peak heating load of the Large Snowflake, Small Snowflake, Tunnel, and the expanded Link areas. At this size, the cooling demand will also be met. The new mechanical infrastructure will tie into the existing heating and cooling water distribution networks for the Large and Small Snowflake. The piping coming from the existing heating and cooling plants will be capped off at the Link.

Similar to the Lake Water Cooling Heat Exchanger measure, this measure has the opportunity to showcase the goal of sustainability and Net Zero Carbon by displaying the inner workings of the system. The possible addition to the Link will provide the ideal conditions to install and display this system. This measure removes a significant portion of the science centre heating energy from the natural gas boilers, thus potentially reducing GHG emissions in 2050 by 50%. The implementation year for this measure is 2032 since the construction on the expanded Link is anticipated to happen in this timeframe. As the timeline for the expansion is not yet confirmed, this implementation date may change as the plans are finalized. In the situation where the expansion is not completed, this measure will also be cancelled. As a result, the Air-Source Heat Pump measure will be adjusted such that the capacity of the heat pump will be enough to provide heating and cooling to the entire facility. The boilers will continue to operate to provide heating to the Entrance Building and the Education Building.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2032	111,355	-308,870	3,970	$898,950	$4,750,000

Air-Source Heat Pump

Following the construction of the expanded Lobby and Link and the installation of the water-source heat pump, the existing heating system will be oversized for the remaining areas that it serves. It will only be serving the Entrance Building and the SPU. There will be an opportunity to electrify and reduce the overall size of the heating plant by installing an air-source heat pump. This heat pump will be sized to meet the demand of the Entrance Building and Education Building. The air-source heat pump will need a capacity of 150 tons to meet the heating demand of these areas. The heat pump can provide hot water at temperatures up to 140°F.

Under current building operations, the hot water temperature is adjusted based on the outdoor air temperature. For the coldest temperatures, the hot water temperature setpoint is 180°F. The air-source heat pump is unable to provide hot water at such a high temperature given the technologies that are currently available. The outdoor temperatures at which the existing hot water temperature setpoint is higher than 140°F are too low for an air-source heat pump to draw heat. Therefore, a supplemental heating source will be required for the coldest outdoor temperatures.

This measure is assuming that an electric resistance boiler will be installed to provide supplemental heating. It is expected that the electric resistance boiler will only operate at outdoor air temperatures below -12°C. It is important to note that the current level of technological sophistication of air-source heat pumps necessitates a supplemental heating source in order to operate in Sudbury's climate. As the technology continues to advance, it is expected that the operating window of air-source heat pumps will widen. The analysis of how often the supplemental electric resistance boiler compared to the air-source heat pump is based on the current level of technology. It is expected that this measure will be implemented in 2036 when the existing new boilers are set to reach the end of their effective life. At that time, the technological landscape of heat pumps may differ. It is therefore recommended that a more detailed analysis of the operations of the air-source heat pump be conducted nearer to the implementation date.

The energy and GHG emissions reduction for this measure assumes that the Water-Source Heat Pump measure is implemented at the described timeline. If that project is delayed or cancelled, the capacity of the air-source heat pump will be adjusted to provide heating and cooling to the entire science centre.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2036	93,675	-733,404	2,582	$(1,061,636)	$1,875,000

Solar PV Array

Science North currently operates a large solar PV array on site. This source of on-site electricity generation reduced the effective electricity consumption in Science North by 7% in 2023. It is expected that the annual electricity consumption will increase as the science centre undergoes electrification. Utility costs for electricity is higher than natural gas, despite the higher escalation rate for natural gas. Thus, it is important to minimize the amount of electricity consumption increase.

One part of the electricity cost solution is to increase the amount of electricity generated on site by increasing the size of the existing PV array. A study was conducted in 2014 which identified potential areas to install the PV system.

Figure 33 shows the locations that were presented in the study. The selected location for this measure of those previously identified is located over the surface parking lot and is known as Location 1. Structural supports will need to be constructed to provide a stable platform for the PV panels. This location provides a PV array that would be approximately 4,000 ft^2 in total size.

Another possible solution is to incorporate a new solar PV array onto the roof of the Lobby and Link expansion. Based on the concept design described in the Building Description section, there will be approximately 20,000 ft^2 of roof area available on this expansion. The anticipated electricity savings for this measure assumes only a 4,000 ft^2 array at current levels of solar PV panel efficiency. The anticipated installation year for this measure is 2040.

The anticipated GHG emissions savings for this measure uses the Marginal Emissions Factor to calculate total savings. An explanation for the Marginal Emissions Factor can be found in the Electricity Analysis section of this report.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2040	0	131,478	413*	$383,514	$200,000

* - Uses the Marginal Emissions Factor for electricity

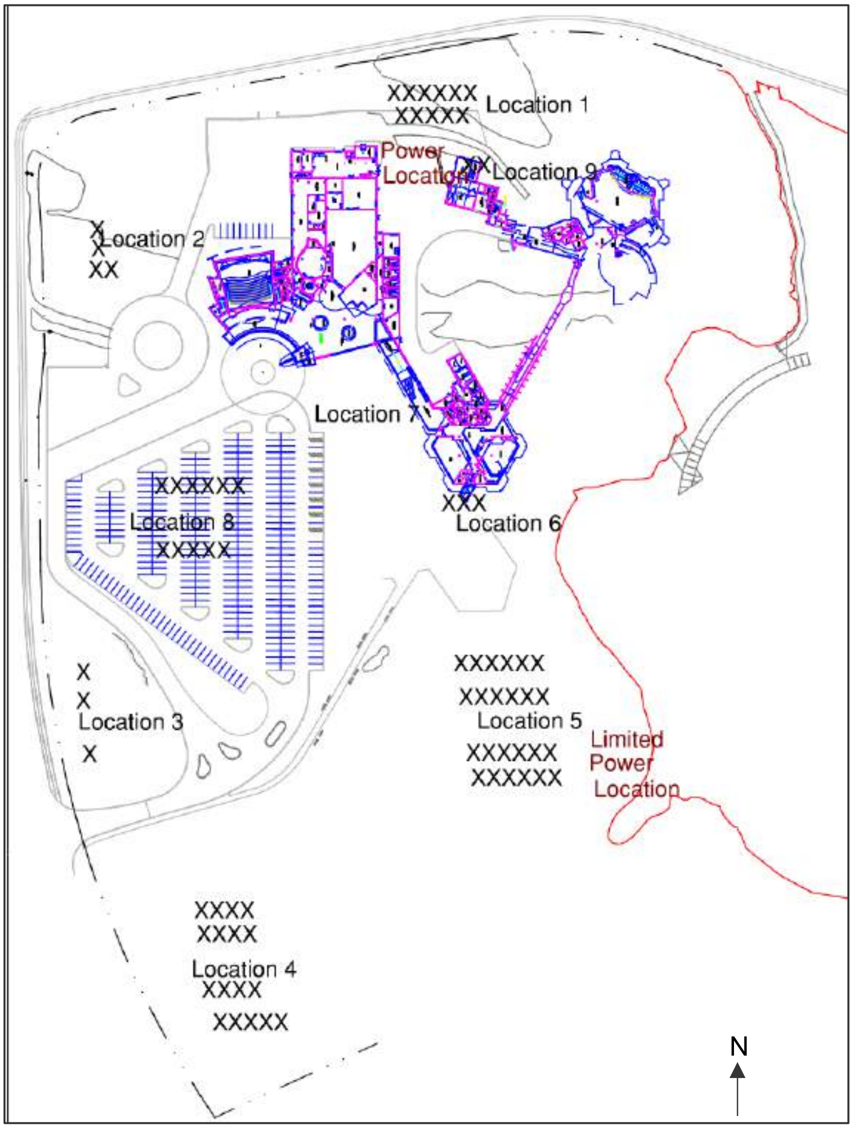


FIGURE 33: POSSIBLE SOLAR PV ARRAY INSTALLATION LOCATIONS - 2014 STUDY

Deep Retrofits Summary

The Deep Retrofits for Science North are a combination of planned upgrades and system opportunities that are optimized with the surrounding environment. The overall implementation timeline of the Deep Retrofits ranges from 2026 to 2036 which is in accordance with the lifespans of the existing equipment and planned upgrades and expansions. Figure 34 shows the expected decrease in emissions compared to the BAU scenario over time. The total energy and GHG emissions reduction associated with the Deep Retrofits is summarized in the table below. These measures are anticipated to reduce the GHG emissions by 89%.

Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction vs BAU	Utility Cost Savings (2025-2050)	Total Capital Cost
209,420	-778,100	7,248	89%	$978,816	$9,625,000

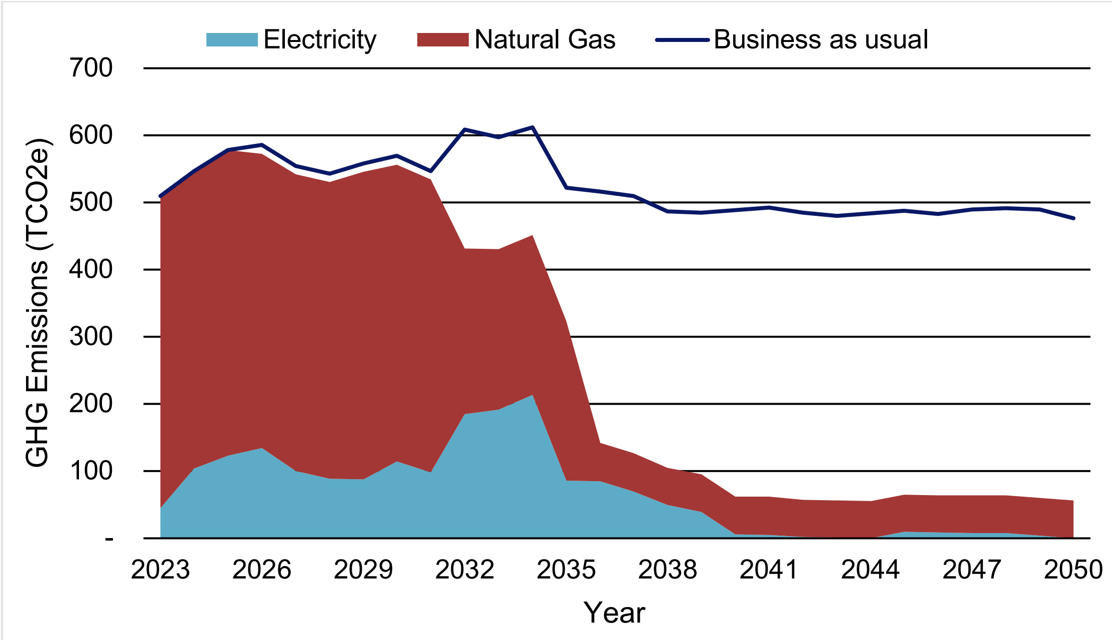


FIGURE 34: EXPECTED GHG REDUCTION THROUGH DEEP RETROFITS – SCIENCE NORTH

NOT RECOMMENDED MEASURES

A number of measures were analyzed but not recommended for this Net Zero Carbon Plan. These measures and the associated reasons for not recommending them are presented in Table 14.

TABLE 14: MEASURES CONSIDERED BUT NOT RECOMMENDED – SCIENCE NORTH

Measure	Reason Not Recommended
Roof Replacement – Entrance Building	Investigated in part to increase the structural strength of the roof to accommodate a solar PV array. Found to be economically infeasible with small impact on GHG reduction.
Exhaust Air Heat Recovery	Air-handling units all have return air. Minimal dedicated exhaust air that is not near air intakes.
Free Cooling Heat Exchanger	No space in existing mechanical room and minimal energy savings available during shoulder seasons.

Energy Conservation Measures – Dynamic Earth

The approach for analyzing ECM's for Dynamic Earth followed the same general principles as for Science North. Measures were considered based on load reduction, fuel switching, and additional renewable energy generation. As with Science North, the implementation year for each measure is based on the existing Capital Plan for Dynamic Earth and the remaining lifespan of the existing equipment.

QUICK WINS

Occupancy and Daylight Sensors

As previously explained, Dynamic Earth recently replaced the vast majority of the lighting to LED. At the time of the site review, approximately 99% of the lighting had been upgraded. However, the primary controls of the lighting are from staff turning off the lights manually. Therefore, the only remaining opportunities to reduce the lighting load at Dynamic Earth will be through the installation of daylight and occupancy sensors. According to the ASHRAE Level I audit conducted in 2021, the storage areas and washrooms already have occupancy sensors. There are other locations at Dynamic Earth where occupancy and daylight sensors make sense for installation. Installing these sensors in strategic areas of intermittent occupancy and near windows can further reduce the electricity consumed by lighting.

The areas that are good candidates for the installation of occupancy sensors include the food services areas, the programming space directly adjacent to the food services area, the entrance lobby, the small theatre on the lower level, the mechanical room, and the lower level programming space.

The level of effort expected for this measure is minimal. It is expected that the sensors are installed and connected to the lighting controls in a minimal amount of time in each area. There will be little impact to the operations of the building. The areas where an installation is occurring will need to be vacant for the time of installation. Ideally, this measure can be completed during a regular schedule shutdown of the science centre.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	Utility Cost Savings (2025-2050)	Capital Cost
2027	0	4,404	2	$ 18,894	$7,300

Convert Domestic Water Heaters to Heat Pumps

The domestic hot water heater at Dynamic Earth is a natural gas-fired heater and storage tank. There is an opportunity to quickly and relatively easily convert this system away from natural gas to electric by installing a heat pump domestic water heater. These systems are commercially available in standard sizes and are offered at a minimal cost premium compared to a like-for-like replacement.

According to the *Lifecycle Asset Condition Report* conducted by Infrastructure Ontario in 2020, the domestic water heater is at the end of its expected life and can be replaced any time. Therefore, this measure is a like-for-similar replacement of this system to an electrified solution.

This measure is expected to have a minimal level of required effort. It is simply a changeout of the existing equipment with an electrified equivalent. This measure is also expected to have a minimal impact on operations. Following a quick pause in service to replace the water heater, there is expected to be no additional work required from the building operations team.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	Utility Cost Savings (2025-2050)	Capital Cost
2026	2,177	-9,643	98	$ 4,054	$56,250

Quick Win Summary

When all of these measures are implemented, there will be a corresponding decrease in GHG emissions. Figure 35 below shows the expected decrease in emissions compared to the BAU scenario over time. In 2050, it is expected that the Quick Win measures will be responsible for a 3% reduction in GHG emissions.

Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	GHG Reduction vs BAU	Utility Cost Savings (2025-2050)	Total Capital Cost
2,177	-5,239	100	3%	$ 22,948	$ 63,550

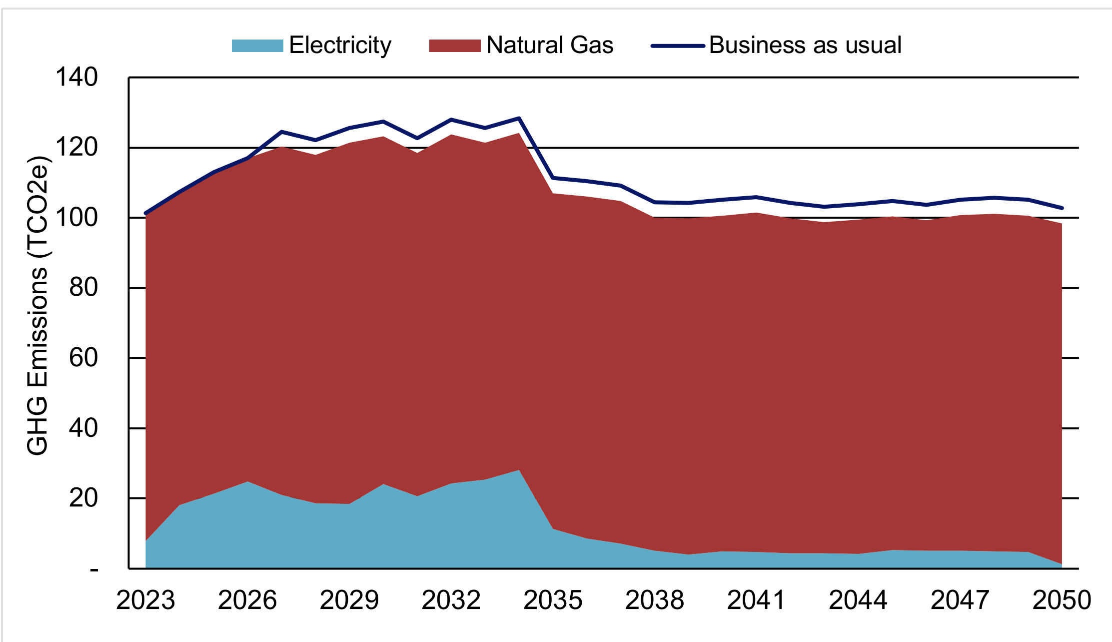


FIGURE 35: EXPECTED GHG REDUCTION THROUGH QUICK WINS - DYNAMIC EARTH

DEEP RETROFIT MEASURES

Alongside and in addition to the Quick Win opportunities, there are a number of large capital measures that will have a significant impact on GHG emissions at Dynamic Earth. As with the Deep Retrofit measures described for Science North, these measures will also require more planning and design compared to the Quick Win measures.

Building Envelope Upgrades

During the investigation, there were multiple comments about the various issues surrounding thermal comfort and building envelope issues for both staff and visitors. Examples of this include the notable gap between the doors at the lower gallery exit, the wide temperature variation in the Office located next to the Chasm on the ground floor, and the accumulated moisture between the window panes for nearly all of the windows in the entrance lobby. This measure addresses these concerns by replacing the aged windows, closing the air gap at the exit door, and providing insulation in the wall between the Chasm and the Office space.

The window replacement would require a significant level of effort and disruption during the construction period. There will need to be coordination between the construction team and the building's operations to determine the ideal timing of the window retrofits. The other retrofits are expected to have a lower level of disruption. The expectation would be that the Office space be vacant for the duration of the construction process.

The expected implementation date of 2030 provides adequate time to plan the measure and confirm funding. The gap in the exit doors does create a draft of unventilated air and in winter ice build-up has been observed on the doors. Beyond just energy and GHG emissions savings, this measure will improve the overall thermal comfort in the space.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	Utility Cost Savings (2025-2050)	Capital Cost
2030	2,980	0	124	$58,758	$ 937,500

Air-Source Heat Pump Packaged Rooftop Units

Dynamic Earth currently operates 13 packaged rooftop heating and cooling ventilation units to provide conditioned air to the vast majority of the building areas. All of the existing units use natural gas-fired furnaces to provide heating. There is an opportunity to electrify these systems by replacing these units with air-source heat pump packaged rooftop units. According to the *Lifecycle Asset Condition Report* conducted by Infrastructure Ontario, the existing rooftop units are at various stages of their life cycle. It is recommended that these units are replaced in phases according to their remaining life with heat pump units. There are four units that are currently slated for replacement in the near future. Given their expected lifespan, the final phase for replacing the rooftop units is 2042. The expected phases for replacing the units is as follows:

- Phase 1: AC-3, AC-4 - 2027
- Phase 2: AC-5, AC-6 - 2034
- Phase 3: AC-7, AC-8, AC-9 - 2038
- Phase 4: RTU 10, RTU 11, RTU 12, RTU 13 - 2042

The savings in this measure also incorporates the anticipated installation of the Building Automation System. As these units are the primary form of heating, cooling, and ventilation, they will be the equipment most affected by the updated controls.

The level of effort expected for this measure is not much higher than a similar like-for-like replacement. There will be additional effort required for capping off the existing gas lines if a unit with an electric resistance supplemental heating system is installed. There is expected to be little to no significant impact to operations during the equipment replacement. There may be additional monitoring and maintenance required to make sure the systems are operating as intended, but nothing significantly different to the existing systems.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	Utility Cost Savings (2025-2050)	Capital Cost
2027-2042	34,630	-245,906	957	$(367,027)	$ 623,000

Air-Source Heat Pump

Besides the rooftop units and the domestic water heater, the only major natural gas-fired equipment at Dynamic Earth is the hot water boiler plant. This system can be replaced with an air-source heat pump. This heat pump would continue to supply the perimeter cabinet units with hot water. While analyzing this measure, it was found that the current boiler plant is likely oversized for the level of service it provides. Therefore, there is also an opportunity to provide a smaller capacity air-source heat pump. This measure assumes a heat pump with a heating capacity of 60 tons. The heat pump is designed to provide heating temperatures up to 140°F.

Under current building operations, the amount of water going to each cabinet unit is varied based on the demand in each place served. The demand from each cabinet unit is determined by the manually adjusted thermostat located on the walls near the cabinet heaters. These systems are likely to be replaced during the BAS upgrade. As such, the cabinet heaters will be automatically controlled – leading to further savings. However, in order to perform an “apples-to-apples” comparison, an updated controls scheme is not assumed for this measure individually. This measure also does not incorporate the costs of new cabinet heaters. It is likely that the existing units will be replaced at the end of their effective lifespans – likely before the boilers reach the end of theirs.

For the supplemental heating source, an electric resistance boiler is used for this measure. It is expected that the electric resistance boiler will only operate at outdoor air temperatures below -12°C. It is important to note that the current level of technological sophistication of air-source heat pumps necessitates a supplemental heating source in order to operate in Sudbury’s climate. As the technology continues to advance, it is expected that the operating window of air-source heat pumps will widen. In calculating the energy savings for this measure, how often the supplemental electric resistance boiler operates compared to the air-source heat pump is based on the current level of technology. It is expected that this measure will be implemented in 2039 when the existing boilers are set to reach the end of their effective life. At that time the technological landscape of heat pumps may differ. It is therefore recommended that a more detailed analysis of the operations of the air-source heat pump be conducted nearer to the implementation date.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2039	9,448	-57,142	218	$ (7,547)	$ 770,000

Solar PV Array

There currently is a large solar PV array at Dynamic Earth. This source of on-site electricity generation reduced the effective electricity consumption at Dynamic Earth by 17%. With the expected electrification of the science centre, it is expected that the annual electricity consumption will increase. The electrification is expected to increase the total utility costs as electricity will be more expensive than natural gas in the medium-term. The best way to offset these additional costs is by installing more on-site electricity generation via an expanded solar PV array.

The location for the new array is on the roof of the Auditorium. There is about 2,000 ft^2 of space available for an additional solar PV array. Given that the roof is not at the ideal azimuth angle for solar PV generation, the total area of PV panels will be less than 2,000 ft^2.

The assumed total size of the array in this area is 1,000 ft^2. The array could be installed any time, but the implementation year has been selected to give enough time for the proper planning and execution of the project. It is recommended that a study of the structural strength of the roof above the large theatre in the entrance area be complete to confirm there is adequate strength to carry the additional weight of the PV array.

The anticipated GHG emissions savings for this measure uses the Marginal Emissions Factor to calculate total savings. An explanation for the Marginal Emissions Factor can be found in the Electricity Analysis section of this report.

Implementation Year	Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_2e)	Utility Cost Savings (2025-2050)	Capital Cost
2040	0	9,714	266*	$ 22,771	$ 74,400

* - Uses the Marginal Emissions Factor for electricity

Deep Retrofits Summary

The Deep Retrofits for Dynamic Earth are a combination of planned upgrades and opportunities based on the surrounding nature. As a result of the existing equipment lifespans and other planned upgrades, the overall implementation timeline of the Deep Retrofits ranges from 2027 to 2042. The total energy and GHG emissions reduction associated with the Deep Retrofits is summarized in the table below. These measures are anticipated to reduce the GHG emissions by 97%.

Annual Natural Gas Reduction (m^3)	Annual Electricity Reduction (kWh)	GHG Reduction 2025-2050 (TCO_{2e})	GHG Reduction vs BAU	Utility Cost Savings (2025-2050)	Total Capital Cost
47,058	-293,334	1,564	97%	$(293,045)	$ 2,405,000

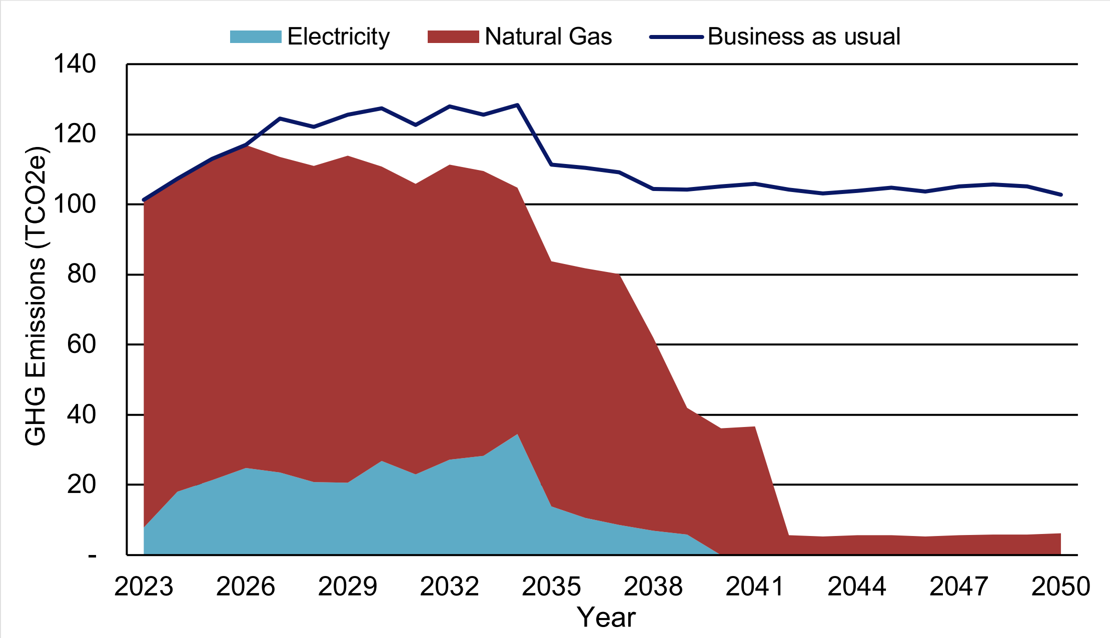


FIGURE 36: EXPECTED GHG REDUCTION THROUGH DEEP RETROFITS - DYNAMIC EARTH

NOT RECOMMENDED MEASURES

A number of measures were analyzed but not recommended for this Net Zero Carbon Plan. The measures and the associated reasons for not recommending them are presented in Table 15.

TABLE 15: MEASURES CONSIDERED BUT NOT RECOMMENDED - DYNAMIC EARTH

Measure	Reason Not Recommended
Ground-Source Heat Pump	Borehole digging deemed not economically feasible.
Exhaust Air Heat Recovery	Packaged ventilation units do not have integrated heat recovery. Would require full reworking of the ventilation systems. High capital cost required for low GHG savings.
Free Cooling Heat Exchanger	No chilled water system and minimal energy savings available during shoulder seasons.

Net Zero Carbon Pathways

SCIENCE NORTH

The purpose of this report is not only to identify the measures to decarbonize Science North, but to also identify the ideal timeline to implement these measures. As mentioned previously, the measure implementation timeline is informed by the existing Capital Plans and the lifespans of the installed equipment. The implementation year for each measure is listed with the measure descriptions in the previous section. A final summary of all measures expected to be implemented is in Table 16 below. Figure 37 shows the final decarbonization timeline for Science North. There are interactive effects between measures, so the total energy reduction achieved through the pathway is not just an addition of the individual measures. For example, the window improvements will reduce the overall heating demand in the building, reducing the amount of heating energy required and reducing the overall impact of the electrification measures.

TABLE 16: SCIENCE NORTH ECM SUMMARY TABLE

ECM	Natural Gas Reduction (m^3/yr)	Electricity Reduction (kWh/yr)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction (% of Baseline)	Utility Cost Reduction 2025-2050	Capital Costs	Implemented Year
Quick Wins	35,187	-41,977	1,605	11%	$580,540	$657,550	2027
Window Upgrades	4,391	58,000	253	6%	$420,688	$2,000,000	2026
Lake Water Cooling	0	74,696	29	4%	$337,300	$800,000	2032
Water-Source Heat Pump	111,355	-308,870	3,970	37%	$898,949	$4,750,000	2032
Solar PV Array	0	131,478	413*	10%	$383,514	$200,000	2040
Air-Source Heat Pump	93,675	-733,400	2,582	32%	$(1,061,636)	$1,875,000	2036
Total	**244,608**	**-820,077**	**8,853**	**100%**	**$1,559,355**	**$10,282,500**	

* - Using the Marginal Emissions Factor to calculate emissions reduction

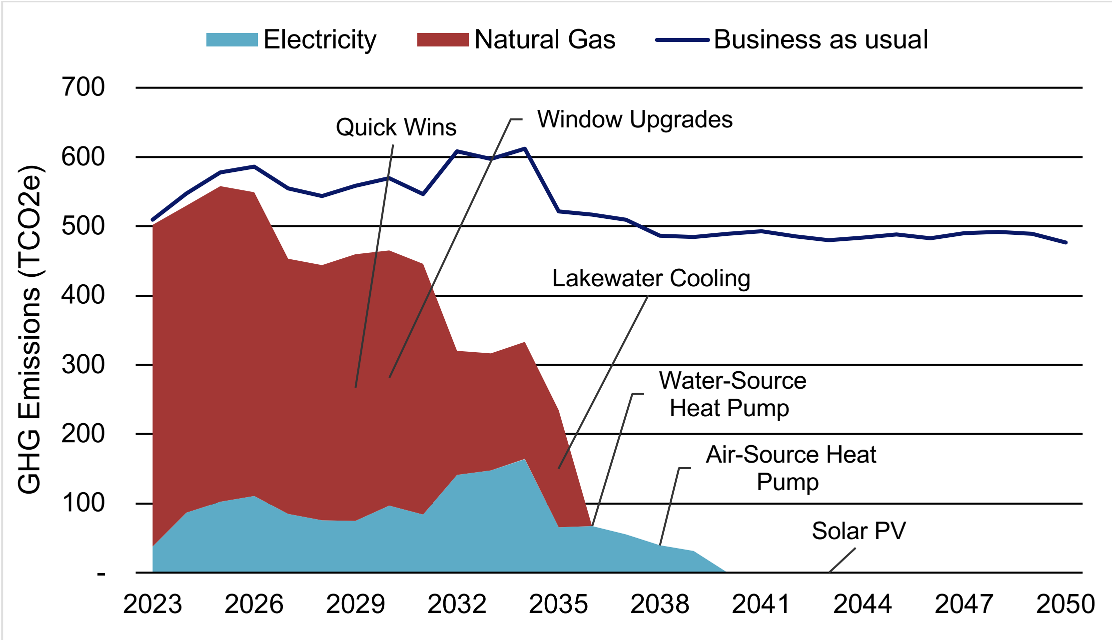


FIGURE 37: FINAL DECARBONIZATION TIMELINE - SCIENCE NORTH

By 2050, it is expected that Science North as a facility will be fully decarbonized. It is expected that with the expanded solar PV array, that the annual emissions related to electricity consumption will be fully offset. It is also expected that measures be taken to track the performance of each measure and monitor the progress towards Net Zero Carbon. Should any of the measures be cancelled or reduced in scope, there may be residual emissions by 2050 that will require offsetting. There are currently options for purchasing of carbon offsets that will likely be available in 2050. There are also opportunities to purchase Renewable Energy Credits (REC's) in which an investment is made in a renewable energy project and the purchaser receives the carbon offset benefit of the investment. As the carbon market continues to mature, there will likely be more options available to verifiably offset any remaining emissions at Science North.

DYNAMIC EARTH

A Net Zero Carbon Pathway timeline to decarbonize Dynamic Earth was also established. The measure implementation timeline is informed by the existing Capital Plans and the remaining lifespan of the installed equipment. Table 17 lists the implementation year for each measure. Figure 38 shows the final decarbonization timeline for Dynamic Earth. As with Science North, interactive effects between measures results in total expected energy reduction that differs from simply adding up the individual measures.

TABLE 17: DYNAMIC EARTH ECM SUMMARY TABLE

ECM	Natural Gas Reduction (m^3/yr)	Electricity Reduction (kWh/yr)	GHG Reduction 2025-2050 (TCO_2e)	GHG Reduction (% of Baseline)	Utility Cost Reduction 2025-2050	Estimated Capital Costs	Implemented Year
Quick Wins	2,177	-5,239	100	3%	$ 22,948	$ 63,550	2026
Envelope Upgrades	2,980	0	124	5%	$58,758	$ 937,500	2030
Rooftop Unit Heat Pumps	34,630	-245,906	957	58%	$(367,027)	$ 623,000	2027-2042
Air-Source Heat Pump	9,448	-57,142	218	15%	$(7,547)	$ 770,000	2039
Solar PV Array	0	9,714	266*	20%	$ 22,771	$ 74,364	2040
Total	**49,235**	**-298,573**	**1,665**	**100%**	**$(270,096)**	**$ 2,468,414**	

* - Uses the Marginal Emissions Factor for electricity

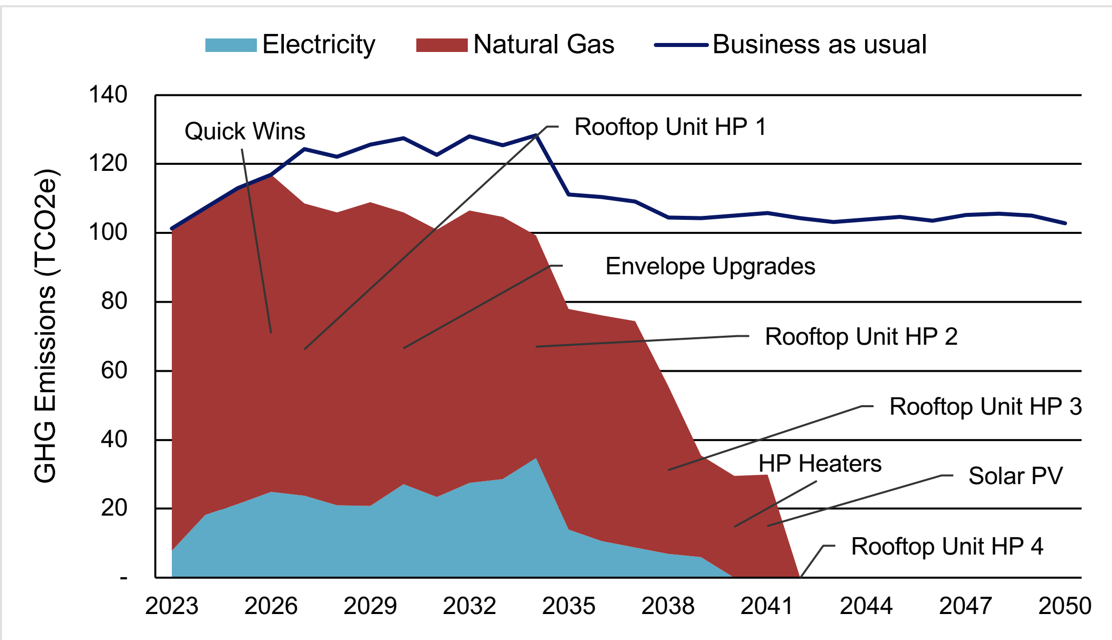


FIGURE 38: FINAL DECARBONIZATION TIMELINE - DYNAMIC EARTH

By 2050, it is expected that Dynamic Earth as a facility will be fully decarbonized. It is expected that with the expanded solar PV array, that the annual emissions related to electricity consumption will be fully offset. It is also expected that measures be taken to track the performance of each measure and monitor the progress towards Net Zero Carbon. Should any of the measures be cancelled or reduced in scope, there may be residual emissions by 2050 that will require offsetting. There are also opportunities to purchase Renewable Energy Credits (REC's) in which an investment is made in a renewable energy project and the purchaser receives the carbon offset benefit of the investment. These options are all currently available and as the carbon market continues to mature, there will likely be more options available to verifiably offset the remaining emissions at Dynamic Earth.

Interim Targets

As part of the Government of Canada's Net-Zero Challenge, two interim GHG emission reduction targets have been set. These targets will assist the Science North team to track their overall progress towards Net Zero Carbon. The shorter-term targets will also help justify implementing the carbon-saving measures earlier in the timeline as opposed to "end loading" multiple measures near 2050.

Canada's Net-Zero Challenge has outlined two approaches to setting interim targets – a "top down" approach and a "bottom up" approach. The "top down" approach chooses two points on a straight line based on the initial GHG emissions in the Baseline Year, and Net Zero Carbon in 2050. The "bottom up" approach uses the proposed ECM's and their expected year of implementation to determine the interim targets. For Science North, a "bottom up" approach has been used to determine the interim targets. The requirements of the Net-Zero Challenge with respect to interim targets using the "bottom up" approach are as follows:

- The first interim target must be at least five years from the date of joining the Challenge, but no later than 2035.
- The second interim target must be at least five years from the date of the first interim target, but no later than 2045.
- The first interim target can be set at a maximum of 40% less than the equivalent interim target based on the "top down" approach.

For Science North, the two years that align with these requirements best are 2035 and 2045. Figure 39 shows the expected emissions reduction at Science North based on the implementation of ECM's compared to the straight line "top down" approach. The interim targets are set to cover both science centres under a single umbrella. The interim targets are to be as follows:

- 2035, the interim target is to be set at a 45% reduction in GHG emissions based on a 2023 Baseline.
- 2045, the interim target is to be set at a 90% reduction in GHG emissions based on a 2023 Baseline.

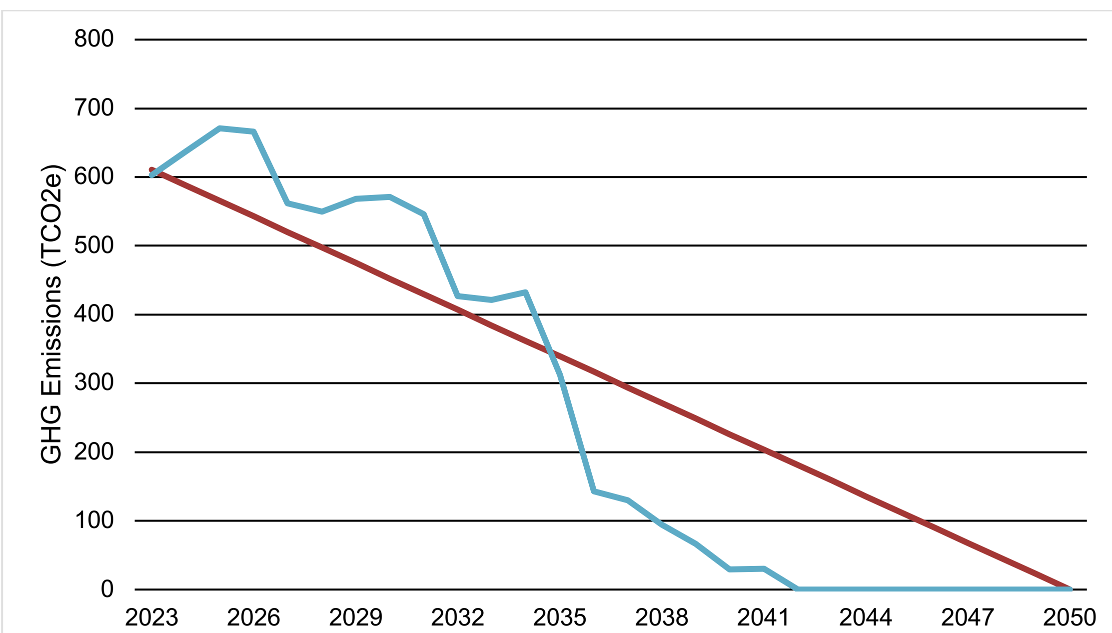


FIGURE 39: EXPECTED GHG EMISSIONS REDUCTION VS STRAIGHT LINE EMISSIONS REDUCTION

As the decarbonization timeline differs between facilities, interim targets can be set for each individual facility as well. The target years of 2035 and 2045 can be applied to the individual science centres. Table 18 below summarizes the interim targets for Science North and Dynamic Earth individually. Figures 40 and 41 show the expected decarbonization timeline plotted against the straight-line method.

TABLE 18: INTERIM TARGETS FOR INDIVIDUAL FACILITIES

Facility	2035 Interim Target (% reduction)	2045 Interim Target (%reduction)
Science North	50%	90%
Dynamic Earth	20%	90%

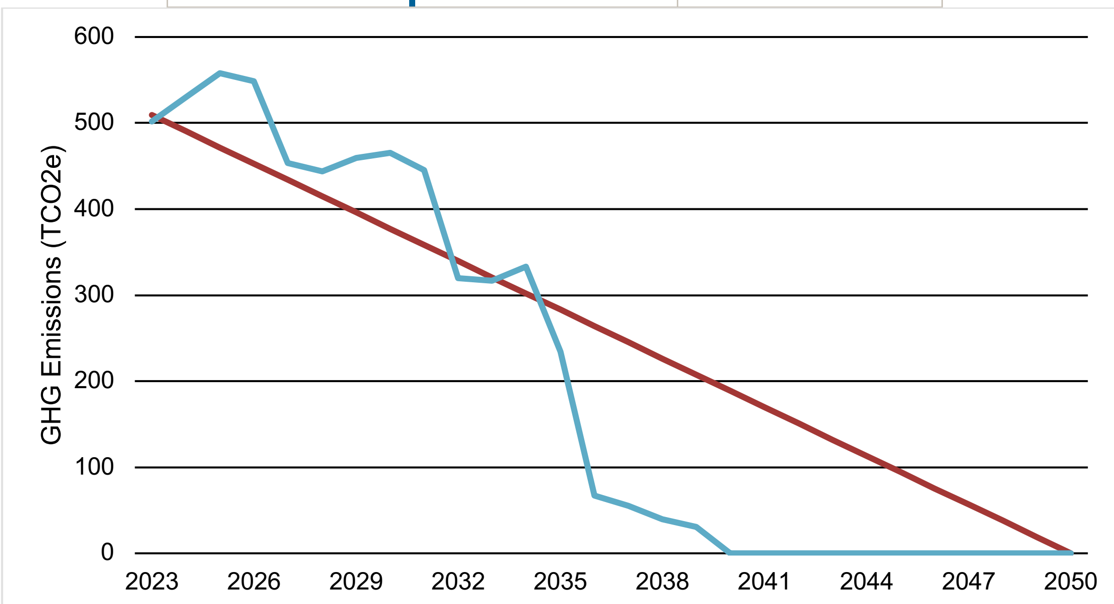


FIGURE 40: EXPECTED GHG EMISSIONS REDUCTION VS STRAIGHT LINE EMISSIONS REDUCTION – SCIENCE NORTH

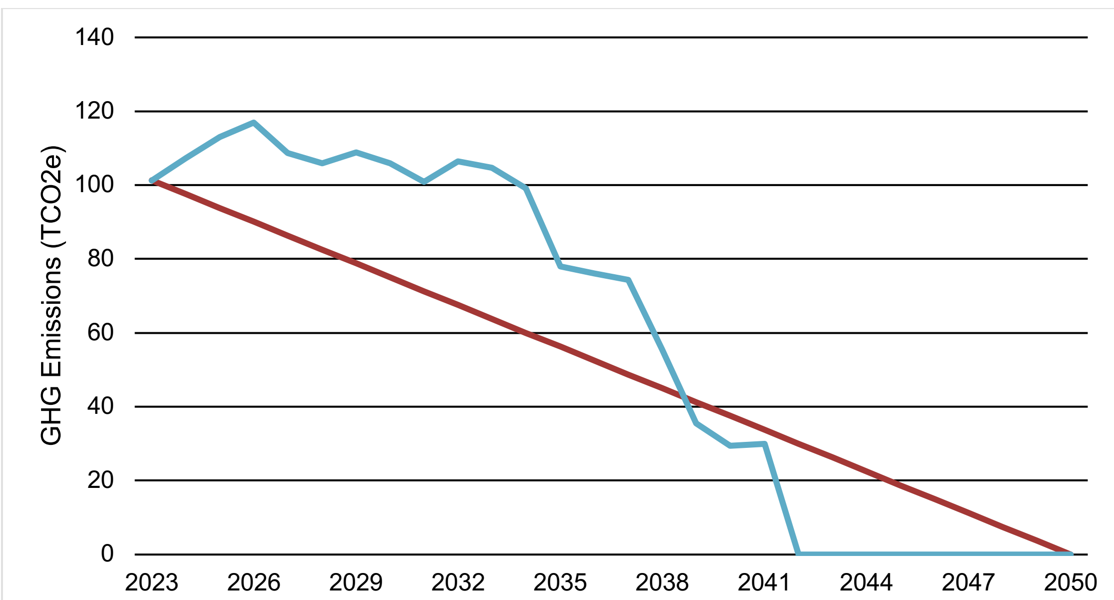


FIGURE 41: EXPECTED GHG EMISSIONS REDUCTION VS STRAIGHT LINE EMISSIONS REDUCTION – DYNAMIC EARTH

Other Considerations

MEASUREMENT AND VERIFICATION

A robust Measurement and Verification (M&V) plan is needed to determine the overall effectiveness of the implemented decarbonization measures. M&V involves the process of using measurements to reliably quantify actual energy savings from an energy savings project within a facility, a process, a building, or a building subsystem. In other words, M&V can be used to verify that an energy efficiency project is achieving its intended savings.

It is recommended that an M&V plan be created to codify how energy performance and GHG emissions reduction will be quantified. The M&V plan is to include the following:

- The approach to quantifying savings
- The key measurements required for quantification
- The computation methods for quantification
- The timing of the retrofit activities
- The roles and responsibilities of involved parties
- The quality assurance requirements associated with the M&V process

In establishing the M&V plan, it is recommended to review the International Performance Measurement and Verification Protocol for guidance to develop the M&V plan. The energy and GHG emissions savings measured using the protocols defined in the M&V plan are to be reported as required by Canada's Net-Zero Challenge.

COMMUNICATION STRATEGY

A well-executed communication strategy for the decarbonization of Science North and Dynamic Earth will play a critical role in its overall success. Executing the measures described in the Net Zero Carbon Plan will involve changes to the science centre and periodic disruptions to operations. Informing the various stakeholders of upcoming projects can aid in the overall success of the projects. It is also recommended that a stakeholder engagement strategy be established that describes how each stakeholder group will be involved as the measures are planned and executed. This strategy can be included in the overall communication strategy.

It is important to clearly define the roles and responsibilities of the parties involved with the Net Zero Carbon Plan. Science North Leadership can define the roles of other stakeholders to determine their level of involvement. The roles and responsibilities need to be defined such that the person or group has well-defined responsibilities. This is especially critical to the execution of the Net Zero Carbon Plan. Attaching responsibilities to specific groups helps to ensure follow-through on tasks and can contribute to the overall success of the Plan.

KEY PERFORMANCE INDICATORS

Key performance indicators (KPI) can be used to demonstrate that the implemented measures are resulting in improved building performance. Key performance indicators can be at the whole-building level or for individual systems.

Selection of the key performance indicators is important for tracking and reporting on energy and GHG emissions. They should be identified such that they give an indication of a measure's – or group of measures' – effectiveness. Key performance indicators can be used to gauge how well Science North is progressing towards meeting the Net Zero Carbon emissions goal.

Key performance indicators can be established alongside the established interim GHG emissions reduction targets. While those targets are primarily a high-level indicator of Science North's progress towards Net Zero Carbon, the key performance indicators can be more targeted to provide a deeper understanding of the performance of implemented measures. Key performance indicators can be selected based on parameters that drive energy consumption. Some examples include, but are not limited to specific equipment electrical demand, equipment downtime, occupancy levels, electricity generation, and monetary savings (i.e. utility costs). Five key performance indicators that can be used to track progress towards Net Zero Carbon can include, but are not limited to:

1. Greenhouse Gas Emissions Intensity (GHGI)

This KPI quantifies the total GHG emissions from the building divided by the GFA. This normalization ensures that Science North is not punished for expanding the facility and consuming more energy as a result. This can be tracked at a frequency determined by Science North. Special tracking of the GHG emission intensity of the electrical grid in Ontario is required in order to understand the emissions related to electricity consumption.

2. Total Energy Use Intensity (TEUI)

This KPI measures the energy consumption divided by the GFA. As with the previous KPI, this normalization ensures that Science North is not punished for expanding the facility. This KPI can be used to track the performance of the implemented measures based on their expected savings calculated in this Plan.

3. Peak Electricity Demand (kW)

This KPI tracks the maximum power demand during a specific time period, typically monthly. Reducing electrical peak demand can lead to cost savings on utility demand charges and help manage the building's overall impact on the electrical grid. As both facilities are expected to electrify their heating systems, it is expected that the annual peak demand will shift from the summer months to the winter.

4. Electricity Generation (kWh)

This KPI measures and tracks the total amount of electricity generated through the solar PV arrays at each site. Both sites are expected to increase the total amount of electricity generation. As a result, tracking the amount of electricity generated will help Science North understand their total effective GHG emissions over time.

5. Number of Visitors

The final KPI tracks the total number of visitors to each site. One of the drivers of energy consumption at both facilities is the number of people present. If there is a month with an unusually high number of visitors, it is expected that there be an increase in total energy consumed for that month as a result. Therefore, if the total number of visitors increases over time, Science North can use this data to justify any adjustments to annual energy and GHG emissions performance targets. Like the increase in GFA should not be a source of punishment in terms of overall performance, nor should an increase in overall popularity of either science centre.

Appendix A – Key Factors

KEY FACTORS

Key factors used for calculations in this report are listed below. This is not a comprehensive list of conversion factors; instead, the table highlights key values that can vary based on reference.

TABLE 19: KEY FACTORS AND SOURCES

	Value		Reference/Comment
Energy Conversions			
Natural Gas Energy Content	36,303	BTU/m^3	https://portfoliomanager.energystar.gov/pdf/reference/Thermal%20Conversions.pdf
	10.64	ekWh/m^3	Standard unit conversion from the above value, based on 3412.14 BTU/kWh
Emissions Factors			
Electricity	23.9	g CO_2e/ekWh	2025 Environment and Climate Change Canada Data Catalogue. Electricity Grid Intensities/Intensites Reseau D'Electricite (Updated 2025-02-26): https://data-donnees.az.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/Energy-Energie/AM%20Scenario%20AMS/Grid-O%26G-Intensities-Intensites-Reseau-Delectricite-P%26G/?lang=en
Natural Gas	1,912	g CO_2e/m^3	2024 National Inventory Report; applying the most recent (2022) factor: https://publications.gc.ca/site/eng/9.506002/publication.html Part 2, Table A6.1-1
	180	g CO_2e/ekWh	Energy conversion using the above factors

Appendix B - Tabulated Utility Data

SCIENCE NORTH

Year 2021	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	148,281	$19,048	2,302	$281	34,368	$10,262
February	133,572	$21,381	3,466	$546	40,231	$11,758
March	133,309	$16,703	15,250	$1,863	26,859	$7,966
April	112,974	$11,886	17,190	$1,895	17,640	$4,804
May	118,500	$18,655	22,720	$3,442	5,289	$1,527
June	141,418	$25,329	20,630	$3,692	1,999	$620
July	188,166	$26,293	19,710	$2,714	909	$334
August	194,596	$33,685	18,230	$2,953	1,247	$631
September	133,667	$18,081	11,370	$1,443	998	$556
October	138,888	$20,665	8,640	$1,280	10,790	$4,611
November	176,287	$23,675	5,470	$729	31,433	$13,418
December	163,397	$19,966	2,214	$269	39,037	$16,884
Total	**1,783,054**	**$255,365**	**147,193**	**$21,107**	**210,802**	**$73,370**

Year 2022	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	156,393	$20,231	1,690	$207	52,807	$23,438
February	145,170	$19,127	3,788	$473	42,832	$19,199
March	174,503	$22,884	10,670	$1,343	35,065	$15,909
April	146,917	$19,011	15,620	$2,021	21,210	$10,077
May	164,246	$23,285	21,530	$2,850	6,726	$3,420
June	164,247	$28,228	20,770	$3,353	1,667	$1,144
July	164,253	$33,462	21,010	$4,021	1,723	$1,224
August	166,881	$31,693	18,430	$3,298	1,723	$1,228
September	145,624	$22,524	13,960	$2,013	7,065	$4,751
October	153,534	$14,562	10,160	$893	12,926	$8,474
November	154,730	$19,565	4,835	$570	25,580	$15,235
December	171,194	$27,075	1,593	$239	35,281	$20,680
Total	**1,907,692**	**$281,647**	**144,056**	**$21,282**	**244,604**	**$124,779**

Year 2023	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	168,285	$17,928	1,119	$112	41,147	$22,996
February	160,617	$20,973	3,768	$467	35,045	$16,004
March	165,535	$23,032	13,080	$1,728	40,569	$17,386
April	147,213	$22,212	13,810	$1,970	14,905	$5,850
May	146,473	$23,111	22,140	$3,221	11,032	$4,383
June	168,827	$30,779	20,480	$3,504	1,667	$745
July	192,811	$36,701	20,790	$3,705	5,908	$2,395
August	186,316	$24,274	15,830	$2,058	1,537	$694
September	169,537	$24,343	15,060	$2,027	3,732	$1,746
October	171,897	$25,706	6,520	$913	21,671	$10,069
November	163,556	$23,234	4,046	$546	31,352	$14,467
December	175,615	$26,896	3,053	$443	36,042	$16,392
Total	**2,016,681**	**$299,189**	**139,695**	**$20,695**	**244,608**	**$113,128**

DYNAMIC EARTH

Year 2021	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	21,551	$2,990	2,365	$316	6,588	$2,245
February	20,270	$3,511	5,257	$912	6,205	$2,109
March	33,405	$4,359	7,102	$925	4,303	$1,474
April	22,656	$2,595	7,599	$1,039	2,476	$878
May	17,635	$2,890	5,784	$946	1,132	$422
June	17,171	$3,247	2,685	$508	62	$46
July	28,157	$4,241	4,216	$638	29	$29
August	30,107	$5,431	8,278	$1,420	8	$25
September	25,071	$3,285	5,843	$751	0	$24
October	33,546	$5,024	4,749	$703	0	$25
November	26,727	$3,736	3,165	$433	3,747	$1,782
December	32,862	$4,031	1,836	$220	4,488	$2,149
Total	**309,158**	**$45,340**	**58,879**	**$8,810**	**29,037**	**$11,207**

Year 2022	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	36,141	$4,627	2,993	$359	7,363	$4,026
February	21,496	$2,966	4,209	$542	6,178	$3,124
March	26,406	$3,513	6,157	$775	4,931	$2,448
April	25,645	$3,400	6,759	$896	2,752	$1,426
May	24,272	$3,463	8,090	$1,066	510	$289
June	25,445	$4,451	8,292	$1,350	4,076	$2,832
July	29,972	$5,898	201,030	$37,023	1,272	$900
August	28,362	$5,288	0	$0	44	$54
September	28,466	$4,134	56,781	$7,686	331	$256
October	31,016	$2,912	105,155	$9,161	1,453	$1,028
November	28,940	$3,558	-97,615	-$11,120	3,414	$2,170
December	34,949	$5,479	83,302	$12,205	4,904	$3,090
Total	**341,109**	**$49,688**	**385,152**	**$59,942**	**37,225**	**$21,644**

Year 2023	Electricity Consumed (kWh)	Electricity Cost	Electricity Generated (kWh)	Generation Revenue	Natural Gas Consumption (m^3)	Natural Gas Cost
January	37,849	$4,015	2,076	$201	6,002	$3,635
February	35,313	$4,647	4,454	$548	8,239	$4,119
March	35,119	$4,974	6,664	$879	9,108	$2,724
April	32,241	$4,850	6,596	$926	4,803	$2,050
May	29,029	$4,256	8,893	$1,222	1,740	$762
June	27,744	$5,067	9,851	$1,685	786	$361
July	29,499	$5,664	-17,048	-$3,079	673	$312
August	28,580	$3,870	30,674	$4,041	870	$396
September	25,832	$3,762	7,530	$1,021	1,581	$741
October	35,380	$5,218	3,072	$425	3,657	$1,847
November	36,301	$5,209	3,422	$473	5,593	$2,809
December	40,316	$6,216			6,183	$3,086
Total	**393,205**	**$57,749**	**66,183**	**$8,342**	**49,235**	**$22,841**

Appendix C – Utility Rates

SCIENCE NORTH

Month	Electricity effective rate ($/kWh)	Natural Gas effective rate ($/m^3)
Apr-18	$0.157	$0.36
May-18	$0.140	$0.37
Jun-18	$0.187	$0.39
Jul-18	$0.148	$0.39
Aug-18	$0.146	$0.39
Sep-18	$0.158	$0.37
Oct-18	$0.136	$0.32
Nov-18	$0.185	$0.32
Dec-18	$0.154	$0.31
Jan-19	$0.129	$0.30
Feb-19	$0.162	$0.23
Mar-19	$0.140	$0.22
Apr-19	$0.128	$0.21
May-19	$0.178	$0.22
Jun-19	$0.168	$0.23
Jul-19	$0.198	$0.24
Aug-19	$0.117	$0.26
Sep-19	$0.185	$0.17
Oct-19	$0.262	$0.24
Nov-19	$0.160	$0.24
Dec-19	$0.138	$0.24
Jan-20	$0.127	$0.25
Feb-20	$0.173	$0.25
Mar-20	$0.152	$0.25
Apr-20	$0.180	$0.24
May-20	$0.132	$0.25
Jun-20	$0.180	$0.31
Jul-20	$0.155	$0.29
Aug-20	$0.157	$0.29
Sep-20	$0.166	$0.26
Oct-20	$0.193	$0.30
Nov-20	$0.160	$0.32
Dec-20	$0.155	$0.31

Month	Electricity effective rate ($/kWh)	Natural Gas effective rate ($/m^3)
Jan-21	$0.129	$0.30
Feb-21	$0.160	$0.29
Mar-21	$0.126	$0.30
Apr-21	$0.104	$0.27
May-21	$0.159	$0.29
Jun-21	$0.179	$0.31
Jul-21	$0.140	$0.37
Aug-21	$0.174	$0.51
Sep-21	$0.136	$0.56
Oct-21	$0.149	$0.43
Nov-21	$0.134	$0.43
Dec-21	$0.122	$0.43
Jan-22	$0.129	$0.44
Feb-22	$0.132	$0.45
Mar-22	$0.131	$0.45
Apr-22	$0.129	$0.48
May-22	$0.143	$0.51
Jun-22	$0.173	$0.69
Jul-22	$0.206	$0.71
Aug-22	$0.191	$0.71
Sep-22	$0.156	$0.67
Oct-22	$0.095	$0.66
Nov-22	$0.127	$0.60
Dec-22	$0.158	$0.59
Jan-23	$0.107	$0.56
Feb-23	$0.131	$0.46
Mar-23	$0.140	$0.43
Apr-23	$0.152	$0.39
May-23	$0.160	$0.40
Jun-23	$0.184	$0.45
Jul-23	$0.192	$0.41
Aug-23	$0.130	$0.45
Sep-23	$0.144	$0.47

DYNAMIC EARTH

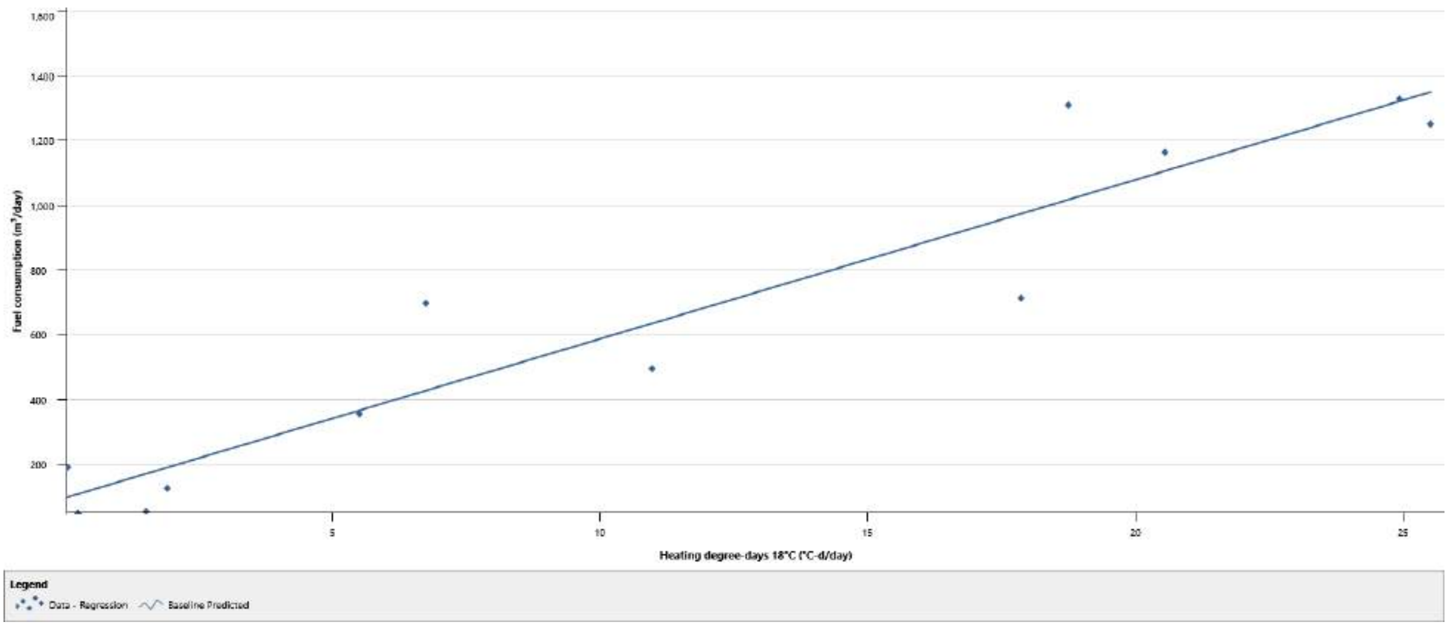
Month	Electricity effective rate ($/kWh)	Natural Gas effective rate ($/m^3)
Apr-18	$0.16	$0.41
May-18	$0.14	$0.56
Jun-18	$0.19	$1.13
Jul-18	$0.16	$-
Aug-18	$0.15	$0.38
Sep-18	$0.16	$0.38
Oct-18	$0.14	$0.37
Nov-18	$0.18	$0.37
Dec-18	$0.15	$0.37
Jan-19	$0.13	$0.36
Feb-19	$0.16	$0.27
Mar-19	$0.14	$0.27
Apr-19	$0.14	$0.26
May-19	$0.18	$0.26
Jun-19	$0.18	$0.26
Jul-19	$0.20	$0.26
Aug-19	$0.13	$0.26
Sep-19	$0.19	$0.48
Oct-19	$0.32	$0.27
Nov-19	$0.17	$0.27
Dec-19	$0.14	$0.27
Jan-20	$0.13	$0.29
Feb-20	$0.18	$0.29
Mar-20	$0.16	$0.29
Apr-20	$0.19	$0.28
May-20	$0.14	$0.28
Jun-20	$0.17	$0.67
Jul-20	$0.16	$0.62
Aug-20	$0.16	$0.73
Sep-20	$0.17	$0.29
Oct-20	$0.19	$0.37
Nov-20	$0.16	$0.35
Dec-20	$0.16	$0.35
Jan-21	$0.14	$0.34
Feb-21	$0.17	$0.34

Month	Electricity effective rate ($/kWh)	Natural Gas effective rate ($/m^3)
Mar-21	$0.13	$0.34
Apr-21	$0.11	$0.35
May-21	$0.16	$0.37
Jun-21	$0.19	$0.74
Jul-21	$0.15	$0.99
Aug-21	$0.18	$0.99
Sep-21	$0.13	$-
Oct-21	$0.15	$-
Nov-21	$0.14	$0.48
Dec-21	$0.12	$0.48
Jan-22	$0.13	$0.55
Feb-22	$0.14	$0.51
Mar-22	$0.13	$0.50
Apr-22	$0.13	$0.52
May-22	$0.14	$0.57
Jun-22	$0.17	$0.69
Jul-22	$0.20	$0.71
Aug-22	$0.19	$1.24
Sep-22	$0.15	$0.78
Oct-22	$0.09	$0.71
Nov-22	$0.12	$0.64
Dec-22	$0.16	$0.63
Jan-23	$0.11	$0.61
Feb-23	$0.13	$0.50
Mar-23	$0.14	$0.30
Apr-23	$0.15	$0.43
May-23	$0.15	$0.44
Jun-23	$0.18	$0.46
Jul-23	$0.19	$0.46
Aug-23	$0.14	$0.45
Sep-23	$0.15	$0.47
Oct-23	$0.15	$0.51
Nov-23	$0.14	$0.50
Dec-23	$0.15	$0.50

Appendix D - RETScreen Results

SCIENCE NORTH

Natural Gas



Equation

Data table	Natural gas
Dependent variable (Y)	Fuel consumption (m^3)
Independent variable (x)	Heating degree-days 18°C (°C-d)
Method	Daily
Weighted	Yes

Validation results

Heating degree-days 18°C	n/a

Regression results

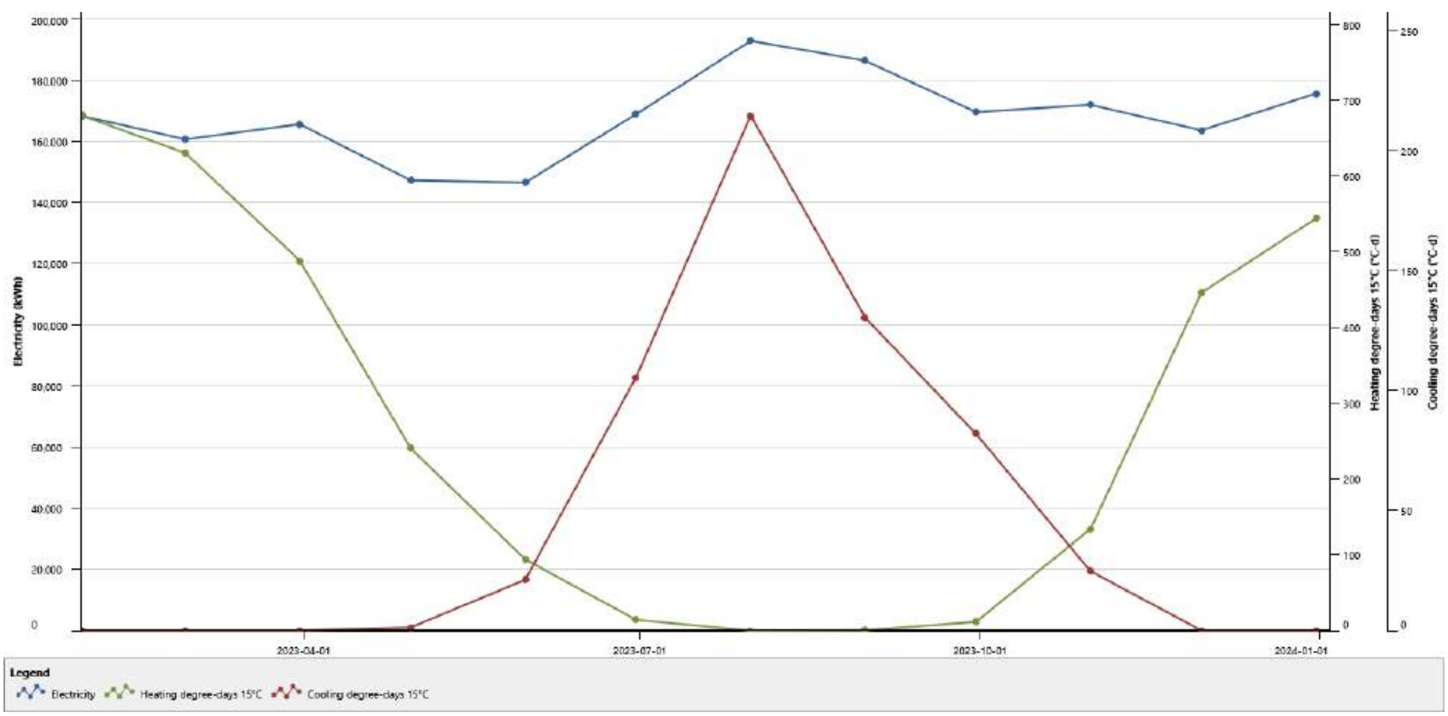
Number of observations:	12
Number of iterations:	13
Residual sum of squares - Absolute:	288,990.9858
Residual sum of squares - Relative:	290,124.7732
Standard error of the estimate:	170.3305
Coefficient of multiple determination (R^2):	0.8975
Coefficient of multiple determination - Adjusted (Ra^2):	0.8873
Root-mean-square error (RMSE):	169.9973
Coefficient of variation of the RMSE:	0.2645
F-test (p-value):	2.9175E-06
Net determination bias error (NDBE):	-0.00366
Durbin-Watson statistic:	3.25326

Coefficient results

Name	Value	Standard error	t-ratio	p-value
a	49.188	5.2395	9.3879	2.827E-06
b	95.2099	76.6186	1.2426	0.2423

Period	Month	Heating degree-days 18°C (°C-d)	Actual Fuel consumption (m³)	Baseline Predicted (m³)	Heating degree-days 18°C (°C-d/day)	Actual Fuel consumption (m³/day)	Baseline Predicted (m³/day)
25	January	772	41,147	40,948	25	1,327	1,321
26	February	714	35,045	37,793	26	1,252	1,350
27	March	581	40,569	31,530	19	1,309	1,017
28	April	329	14,905	19,048	11	497	635
29	May	171	11,032	11,347	6	356	366
30	June	46	1,667	5,115	2	56	171
31	July	2	5,908	3,038	0	191	98
32	August	8	1,537	3,350	0	50	108
33	September	58	3,732	5,701	2	124	190
34	October	209	21,671	13,252	7	699	427
35	November	536	21,352	29,210	18	712	974
36	December	637	36,042	34,273	21	1,163	1,106

Electricity



Equation

Data table	Electricity consumption
Dependent variable (Y)	Electricity (kWh)
Independent variable (x1)	Heating degree-days 15°C (°C-d)
Independent variable (x2)	Cooling degree-days 15°C (°C-d)
Method	Daily
Weighted	Yes

Validation results

Heating degree-days 15°C	n/a
Cooling degree-days 15°C	n/a

Regression results

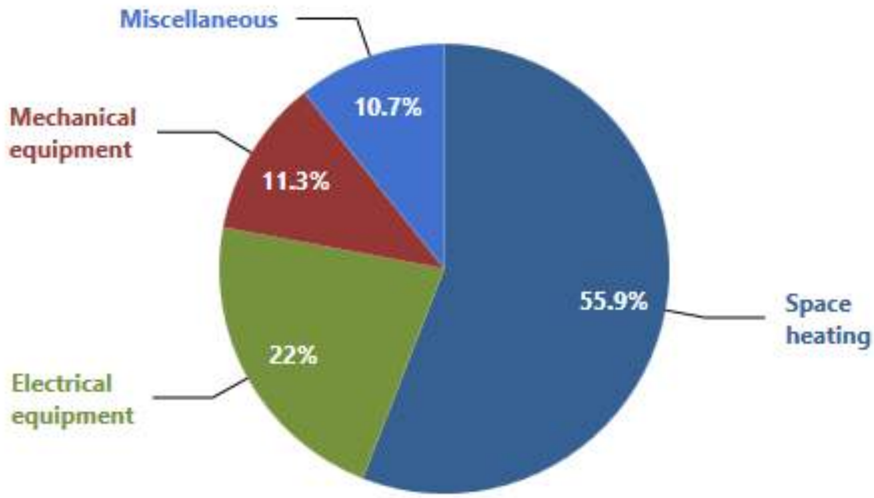
Number of observations:	12
Number of iterations:	13
Residual sum of squares - Absolute:	542,475.1487
Residual sum of squares - Relative:	548,786.5305
Standard error of the estimate:	246.9338
Coefficient of multiple determination (R^2):	0.7109
Coefficient of multiple determination - Adjusted (Ra^2):	0.6466
Root-mean-square error (RMSE):	245.5097
Coefficient of variation of the RMSE:	0.0444
F-test (p-value):	0.0038
Net determination bias error (NDBE):	0.00013
Durbin-Watson statistic:	1.12806

Coefficient results

Name	Value	Standard error	t-ratio	p-value
a	4,867.0666	188.8279	25.7751	9.5974E-10
b	34.1609	12.3027	2.7767	0.0215
c	220.8983	48.1021	4.5923	0.0013

Period	Month	Heating degree-days 15°C (°C-d)	Cooling degree-days 15°C (°C-d)	Actual Electricity (kWh)	Baseline Predicted (kWh)	Heating degree-days 15°C (°C-d/day)	Cooling degree-days 15°C (°C-d/day)	Actual Electricity (kWh/day)	Baseline Predicted (kWh/day)
25	January	679	0	168,285	174,091	22	0	5,429	5,616
26	February	630	0	160,617	157,804	23	0	5,736	5,636
27	March	488	0	165,535	167,550	16	0	5,340	5,405
28	April	240	1	147,213	154,504	8	0	4,907	5,150
29	May	94	21	146,473	158,761	3	1	4,725	5,121
30	June	14	106	168,827	169,815	0	4	5,628	5,660
31	July	0	215	192,811	198,317	0	7	6,220	6,397
32	August	0	130	186,316	179,717	0	4	6,010	5,797
33	September	11	82	169,537	164,509	0	3	5,651	5,484
34	October	134	25	171,897	160,919	4	1	5,545	5,191
35	November	446	0	163,556	161,240	15	0	5,452	5,375
36	December	544	0	175,615	169,455	18	0	5,665	5,466

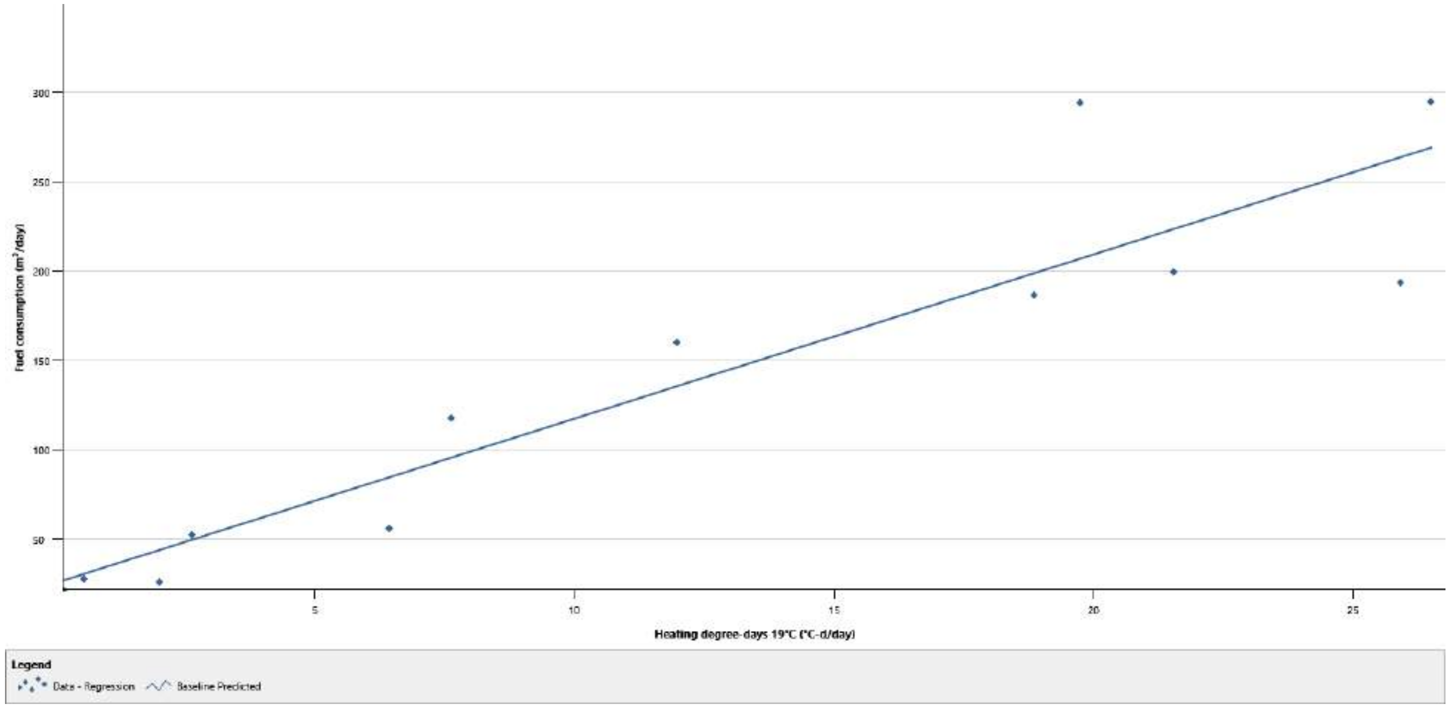
End Use Breakdown



	Energy - base case	
Section	GJ	%
Space heating	9,019	55.9%
Electrical equipment	3,557	22%
Mechanical equipment	1,830	11.3%
Miscellaneous	1,729	10.7%
Lights	786	4.9%
Space cooling	482	3%
Hot water	461	2.9%

DYNAMIC EARTH

Natural Gas



Equation

Data table	Natural gas
Dependent variable (Y)	Fuel consumption (m^3)
Independent variable (x)	Heating degree-days 19°C (°C-d)
Method	Daily
Weighted	Yes

Validation results

Heating degree-days 19°C	n/a

Regression results

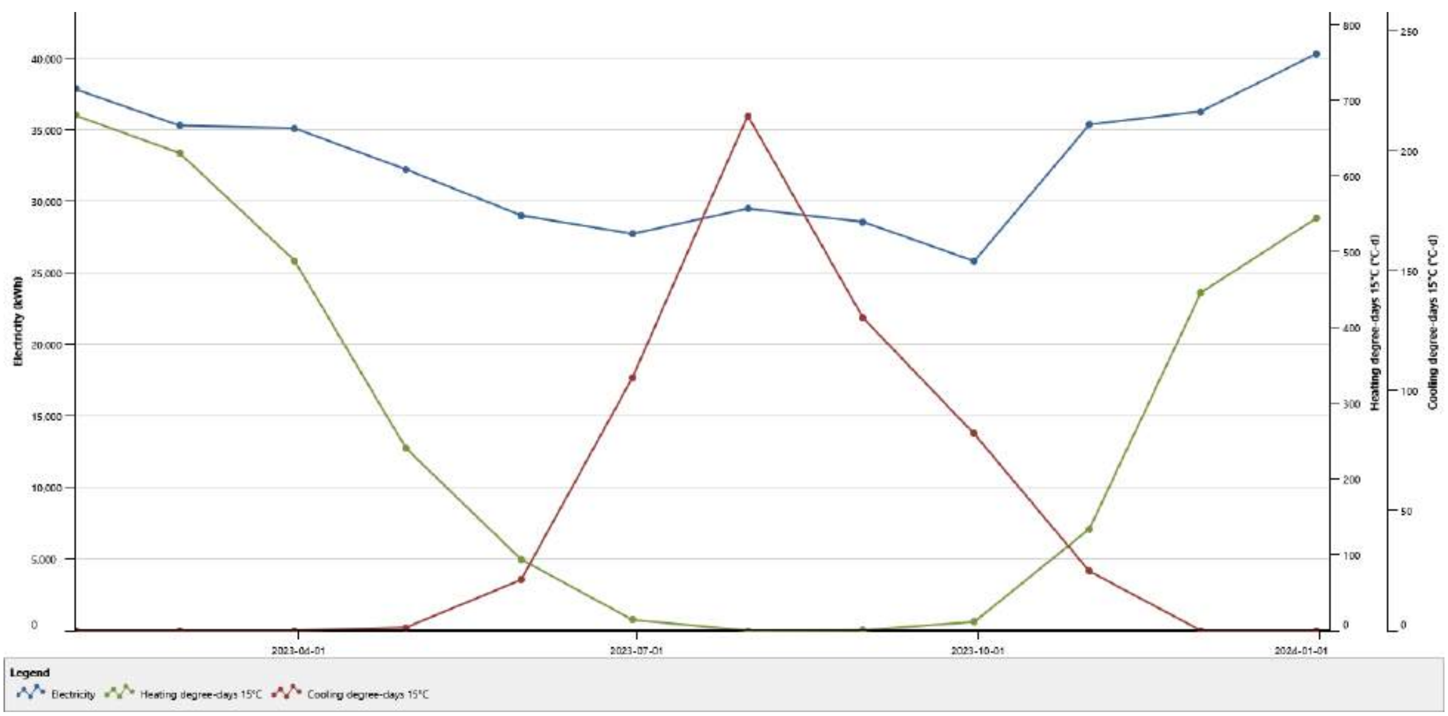
Number of observations:	12
Number of iterations:	11
Residual sum of squares - Absolute:	16,092.5153
Residual sum of squares - Relative:	16,302.0649
Standard error of the estimate:	40.3758
Coefficient of multiple determination (R^2):	0.8514
Coefficient of multiple determination - Adjusted (Ra^2):	0.8366
Root-mean-square error (RMSE):	40.1155
Coefficient of variation of the RMSE:	0.2974
F-test (p-value):	1.9381E-05
Net determination bias error (NDBE):	0.00147
Durbin-Watson statistic:	1.36683

Coefficient results

Name	Value	Standard error	t-ratio	p-value
a	9.1783	0.582	15.7702	2.1589E-08
b	25.5849	8.9503	2.8586	0.017

Period	Month	Heating degree-days 18°C (°C-d)	Actual Fuel consumption (m³)	Baseline Predicted (m³)	Heating degree-days 18°C (°C-d/day)	Actual Fuel consumption (m³/day)	Baseline Predicted (m³/day)
25	January	803	6,002	8,168	26	194	263
26	February	742	8,239	7,528	27	294	269
27	March	612	9,108	6,410	20	294	207
28	April	359	4,803	4,064	12	160	135
29	May	200	1,740	2,624	6	56	85
30	June	60	786	1,317	2	26	44
31	July	5	673	837	0	22	27
32	August	17	870	947	1	28	31
33	September	79	1,581	1,492	3	53	50
34	October	237	3,657	2,964	8	118	96
35	November	566	5,593	5,960	19	186	199
36	December	668	6,183	6,922	22	199	223

Electricity



Equation

Data table	Electricity consumption
Dependent variable (Y)	Electricity (kWh)
Independent variable (x1)	Heating degree-days 15°C (°C-d)
Independent variable (x2)	Cooling degree-days 15°C (°C-d)
Method	Daily
Weighted	Yes

Validation results

Heating degree-days 15°C	n/a
Cooling degree-days 15°C	n/a

Regression results

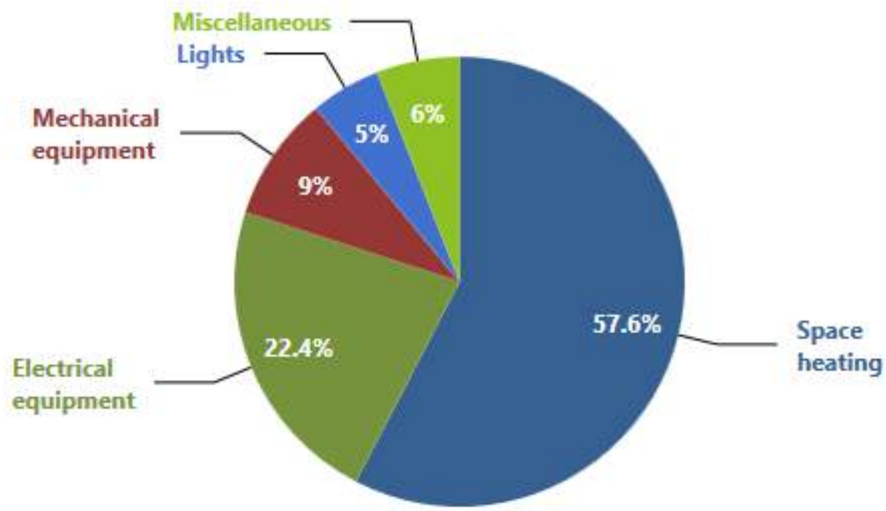
Number of observations:	12
Number of iterations:	14
Residual sum of squares - Absolute:	44,057.4875
Residual sum of squares - Relative:	44,564.3597
Standard error of the estimate:	70.3676
Coefficient of multiple determination (R^2):	0.827
Coefficient of multiple determination - Adjusted (Ra^2):	0.7886
Root-mean-square error (RMSE):	69.9663
Coefficient of variation of the RMSE:	0.0649
F-test (p-value):	0.0004
Net determination bias error (NDBE):	-0.00032
Durbin-Watson statistic:	1.75882

Coefficient results

Name	Value	Standard error	t-ratio	p-value
a	955.8255	53.8094	17.7632	2.5776E-08
b	14.5597	3.5059	4.153	0.0025
c	-5.9527	13.7074	-0.4343	0.6743

Period	Month	Heating degree-days 15°C (°C-d)	Cooling degree-days 15°C (°C-d)	Actual Electricity (kWh)	Baseline Predicted (kWh)	Heating degree-days 15°C (°C-d/day)	Cooling degree-days 15°C (°C-d/day)	Actual Electricity (kWh/day)	Baseline Predicted (kWh/day)
25	January	679	0	37,849	39,524	22	0	1,221	1,275
26	February	630	0	35,313	35,938	23	0	1,261	1,283
27	March	488	0	35,119	36,736	16	0	1,133	1,185
28	April	240	1	32,241	32,168	8	0	1,075	1,072
29	May	94	21	29,029	30,871	3	1	936	996
30	June	14	106	27,744	28,252	0	4	925	942
31	July	0	215	29,499	28,352	0	7	952	915
32	August	0	130	28,580	28,859	0	4	922	931
33	September	11	82	25,832	28,353	0	3	861	945
34	October	134	25	35,380	31,437	4	1	1,141	1,014
35	November	446	0	36,301	35,165	15	0	1,210	1,172
36	December	544	0	40,316	37,548	18	0	1,301	1,211

End Use Breakdown



	Energy - base case	
Section	GJ	%
Space heating	1,716	57.6%
Electrical equipment	667	22.4%
Mechanical equipment	268	9%
Lights	150	5%
Miscellaneous	178	6%
Space cooling	98	3.3%
Hot water	80	2.7%

Appendix E – Summary Tables: Science North

Year	HDD	Electricity Emissions Factor (gCO_2e/kWh)	Utility Rates		Building GFA (m^2)	Business-As-Usual				Net Zero Pathway			
			Natural Gas ($\$/m^3$)	Electricity ($/kWh)		Electricity (kWh)	Natural Gas (m^3)	Total GHG (TCO_2e)	Annual Utility Cost	Electricity (kWh)	Natural Gas (m^3)	Total GHG (TCO_2e)	Annual Utility Cost
2020	3,486	26.8	$0.14	$0.15	18,237	1,876,986	244,608	515	$312,739	1,876,986	244,608	515	$312,739
2021	4,742	29	$0.17	$0.15	18,237	1,635,861	210,802	448	$285,860	1,635,861	210,802	448	$285,860
2022	4,836	33	$0.20	$0.16	18,237	1,763,636	244,604	523	$327,455	1,763,636	244,604	523	$327,455
2023	4,673	23.9	$0.25	$0.16	18,237	1,876,986	244,608	509	$366,186	1,876,986	244,608	509	$366,186
2024	4,454	55.5	$0.31	$0.17	18,237	1,876,986	233,144	547	$385,249	1,876,986	233,144	547	$385,249
2025	4,583	65.3	$0.37	$0.17	18,237	1,876,986	239,897	578	$411,488	1,876,986	239,897	578	$411,488
2026	4,601	76.1	$0.38	$0.18	18,237	1,818,986	235,839	586	$411,780	1,703,006	214,920	538	$383,292
2027	4,636	56.9	$0.41	$0.18	18,237	1,818,986	237,671	555	$428,458	1,802,963	193,871	471	$407,745
2028	4,638	50.4	$0.43	$0.19	18,237	1,818,986	237,775	543	$445,219	1,802,963	193,976	459	$423,172
2029	4,801	50	$0.46	$0.19	18,237	1,818,986	246,308	559	$466,676	1,802,963	202,508	475	$443,207
2030	4,638	65	$0.50	$0.20	18,237	1,818,986	237,775	570	$481,012	1,802,963	193,976	486	$456,025
2031	4,574	55.9	$0.53	$0.21	18,237	1,818,986	234,425	547	$498,391	1,802,963	190,625	463	$471,782
2032	4,650	65.8	$0.57	$0.21	19,352	1,933,786	253,291	608	$553,367	2,845,569	93,938	366	$655,476
2033	4,498	68.4	$0.61	$0.22	19,352	1,933,786	244,848	597	$570,593	1,993,779	89,347	306	$488,885
2034	4,497	76.1	$0.65	$0.22	19,352	1,933,786	244,792	612	$593,644	1,993,779	89,317	321	$505,710
2035	4,478	30.5	$0.70	$0.23	19,352	1,933,786	243,737	522	$617,103	1,993,779	88,743	229	$522,811
2036	4,554	23.3	$0.75	$0.24	19,371	1,935,713	248,203	516	$646,214	2,840,885	-	66	$676,401
2037	4,564	19.1	$0.80	$0.25	19,390	1,937,641	249,004	510	$674,126	2,844,653	-	54	$697,617
2038	4,439	13.6	$0.85	$0.25	19,409	1,939,568	242,286	486	$697,051	2,848,420	-	39	$719,497
2039	4,471	10.7	$0.91	$0.26	19,427	1,941,496	244,309	485	$728,600	2,852,187	-	31	$742,062
2040	4,464	13.1	$0.98	$0.27	19,446	1,943,423	244,159	489	$759,766	2,855,955	-	37	$765,333
2041	4,497	12.9	$1.05	$0.28	19,465	1,945,351	246,242	493	$794,832	2,859,722	-	37	$789,333
2042	4,440	11.9	$1.12	$0.28	19,484	1,947,278	243,297	485	$826,239	2,863,489	-	34	$814,084
2043	4,392	11.7	$1.20	$0.29	19,502	1,949,206	240,848	480	$859,561	2,867,257	-	34	$839,610
2044	4,423	11.5	$1.28	$0.30	19,521	1,951,133	242,821	484	$900,011	2,871,024	-	33	$865,934
2045	4,414	14	$1.37	$0.31	19,540	1,953,061	242,554	488	$939,705	2,874,791	-	40	$893,083
2046	4,364	13.8	$1.47	$0.32	19,558	1,954,988	239,985	483	$978,057	2,878,559	-	40	$921,081
2047	4,430	13.6	$1.57	$0.33	19,577	1,956,916	243,928	490	$1,028,332	2,882,326	-	39	$949,955
2048	4,449	13.4	$1.68	$0.34	19,596	1,958,843	245,235	492	$1,077,368	2,886,093	-	39	$979,732
2049	4436	12.5	$1.80	$0.35	19,615	1,960,771	244,742	489	$1,125,973	2,889,861	-	36	$1,010,441
2050	4480	3.4	$1.93	$0.36	19,633	1,962,698	247,460	477	$1,183,295	2,893,628	-	10	$1,042,111

Appendix F – Summary Tables: Dynamic Earth

Year	HDD	Electricity Emissions Factor (gCO_2e/kWh)	Utility Rates Natural Gas ($\$/m^3$)	Utility Rates Electricity ($/kWh)	Building GFA (m^2)	Business-As-Usual Electricity (kWh)	Business-As-Usual Natural Gas (m^3)	Business-As-Usual Total GHG (TCO_2e)	Business-As-Usual Annual Utility Cost	Net Zero Pathway Electricity (kWh)	Net Zero Pathway Natural Gas (m^3)	Net Zero Pathway Total GHG (TCO_2e)	Net Zero Pathway Annual Utility Cost
2020	3,486	26.8	$0.14	$0.15	3,485	250,279	29,037	61	$41,200	250,279	29,037	62	$41,200
2021	4,742	29	$0.17	$0.15	3,485	250,279	29,037	62	$43,188	250,279	29,037	62	$43,188
2022	4,836	33	$0.20	$0.16	3,485	-44,043	37,225	69	$653	-44,043	37,225	69	$653
2023	4,673	23.9	$0.25	$0.16	3,485	327,022	49,235	101	$65,473	327,022	49,235	101	$65,473
2024	4,454	55.5	$0.31	$0.17	3,485	327,022	46,927	107	$69,063	327,022	46,927	107	$69,063
2025	4,583	65.3	$0.37	$0.17	3,485	327,022	48,286	113	$74,090	327,022	48,286	113	$74,090
2026	4,601	76.1	$0.38	$0.18	3,485	327,022	48,476	117	$76,337	331,416	46,115	113	$76,219
2027	4,636	56.9	$0.41	$0.18	3,894	365,396	54,576	124	$88,843	417,468	44,698	109	$94,334
2028	4,638	50.4	$0.43	$0.19	3,894	365,396	54,600	122	$92,406	417,468	44,718	106	$97,899
2029	4,801	50	$0.46	$0.19	3,894	365,396	56,519	126	$97,019	417,468	46,373	109	$102,382
2030	4,638	65	$0.50	$0.20	3,894	365,396	54,600	127	$100,026	417,468	41,485	106	$103,884
2031	4,574	55.9	$0.53	$0.21	3,894	365,396	53,846	123	$103,713	417,468	40,836	101	$107,481
2032	4,650	65.8	$0.57	$0.21	3,894	365,396	54,741	128	$108,480	417,468	41,607	106	$112,014
2033	4,498	68.4	$0.61	$0.22	3,894	365,396	52,952	126	$111,891	352,278	40,064	100	$101,178
2034	4,497	76.1	$0.65	$0.22	3,894	365,396	52,940	128	$116,531	392,428	33,914	94	$110,190
2035	4,478	30.5	$0.70	$0.23	3,894	365,396	52,716	111	$121,252	392,428	33,747	76	$114,264
2036	4,554	23.3	$0.75	$0.24	3,898	365,732	53,660	110	$127,146	392,845	34,452	75	$119,259
2037	4,564	19.1	$0.80	$0.25	3,902	366,067	53,827	109	$132,779	393,261	34,576	73	$124,067
2038	4,439	13.6	$0.85	$0.25	3,905	366,403	52,401	104	$137,348	446,519	25,535	55	$134,618
2039	4,471	10.7	$0.91	$0.26	3,909	366,739	52,827	104	$143,738	494,917	15,538	35	$142,977
2040	4,464	13.1	$0.98	$0.27	3,912	367,075	52,793	105	$150,039	495,382	15,518	36	$147,940
2041	4,497	12.9	$1.05	$0.28	3,916	367,411	53,232	106	$157,160	495,847	15,779	36	$153,387
2042	4,440	11.9	$1.12	$0.28	3,920	367,746	52,605	104	$163,498	607,434	-	7	$172,692
2043	4,392	11.7	$1.20	$0.29	3,923	368,082	52,084	103	$170,234	608,000	-	7	$178,039
2044	4,423	11.5	$1.28	$0.30	3,927	368,418	52,499	104	$178,473	608,566	-	7	$183,551
2045	4,414	14	$1.37	$0.31	3,930	368,754	52,440	105	$186,545	609,133	-	9	$189,233
2046	4,364	13.8	$1.47	$0.32	3,934	369,090	51,894	104	$194,325	609,699	-	8	$195,091
2047	4,430	13.6	$1.57	$0.33	3,937	369,426	52,726	105	$204,623	610,266	-	8	$201,131
2048	4,449	13.4	$1.68	$0.34	3,941	369,761	53,001	106	$214,652	610,832	-	8	$207,357
2049	4436	12.5	$1.80	$0.35	3,945	370,097	52,894	105	$224,582	611,399	-	8	$213,776
2050	4480	3.4	$1.93	$0.36	3,948	370,433	53,467	103	$236,351	611,965	-	2	$220,393