McGill

GREENHOUSE GAS INVENTORY

2017 REPORTING YEAR

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Executive Summary

Scope

- Reporting period: January 1 – December 31, 2017
- Consolidation approach: operational control
- Operational scope: material Scope 1 and 2 emissions; select Scope 3 emissions
- Protocol: compiled following the guidance of the WBCSD/WRI GHG Protocol

Key Results

- Total **emissions for reporting year 2017 are 56,004 tonnes of CO_2 equivalent (tCO_2e),** reported in Table 8. This represents a **decrease of 4.8% compared to the updated 2015 inventory** (see below).

- Scope 1 emissions – particularly natural gas consumption (58% of total emissions) – continue to make up the majority of McGill University's emissions, contributing 64% overall.

- Notably, **emission reductions occurred across all three scopes compared to 2015.** The most significant reductions were associated with Scope 1 sources such as natural gas (-2,073 tCO_2e) and heating oil (-326 tCO_2e); we also realized Scope 3 emission reductions in natural gas (-184 tCO_2e). Reductions in steam and hot water consumption produced Scope 2 emissions savings of 293 tCO_2e and 88 tCO_2e. Fluctuations in directly financed air travel accounted for reductions of 136 tCO_2e in Scope 3 emissions.

- Emissions increased for some activities. For example, Scope 1 livestock emissions increased due to an increase in headcount (+50 tCO_2e) and Scope 3 emissions from commuting increased as a result of growth in our student and staff populations (+220 tCO_2e). See Table 10 for a detailed data and emissions comparison between 2015 and 2017.

- **Emissions are re-calculated for reporting year 2015.** We did this so that we could update our methodology and expand the scope of our inventory to include additional emission sources, specifically leased properties, jointly managed properties and smaller research stations. **Total emissions for reporting year 2015 are now 58,819 tCO_2e,** an increase of 4,757 tCO_2e from the previous 2015 total (54,062 tCO_2e).

- Avoided emissions from waste management and from refrigerants governed by the Montréal Protocol are reported separately to adhere to the best practice guidance of the GHG Protocol..

- Relevant key performance indicators were calculated for 2017. McGill's **emissions per student enrolment were 1.02 tCO_2e/FTE student and emissions per gross area were 0.038 tCO_2e/m^2,** both of which have decreased since the 2015 inventory. A comparison of these and other metrics against select Canadian and American research universities is provided in the report..

1. Introduction

A greenhouse gas (GHG) assessment, also known as a GHG inventory or a carbon footprint assessment, is a quantified list of an organization's GHG emissions and sources within a chosen scope. It is a valuable and strategic tool for understanding, managing and communicating climate change impacts resulting from an organization's activities – specifically, greenhouse gas emissions.

A. Greenhouse Gas Reporting at McGill

Since 2014, McGill has conducted annual GHG assessments to inform and achieve a number of internal and external targets related to sustainability efforts, emissions reductions initiatives, monitoring & reporting, and compliance. In 2017, McGill launched the Vision 2020: Climate & Sustainability Action Plan, which – among other ambitious goals – committed the University to achieving institutional carbon neutrality by 2040 and making emissions reduction progress in a number of specific categories by 2020. The results of our annual GHG assessments allow us to track and communicate progress against our short- and long-term emissions targets, gauge the impact of implemented reduction initiatives, and identify further reduction opportunities for future action. McGill's GHG emissions are also reported to the Board of Governors annually as one of three strategic key performance indicators linked to sustainability progress.

Externally, data and emissions from our inventory are reported to a number of mandatory and voluntary reporting programs. These include:

- **Greenhouse Gas Reporting Program for GHGs:** Run by Environment Canada at the federal level. We report emissions from the downtown campus as required and voluntarily report emissions for the Macdonald campus.

- **National Pollutant Inventory Report for airborne contaminants excluding GHGs:** Run by Environment Canada and complementary to the above program. We report CO and NO_x for the downtown campus as required and report voluntarily on all other Part 4 substances (e.g. sulphur dioxide, particulate matter, VOCs) for the downtown and Macdonald campuses.

- **Inventaire québécois des émissions atmosphériques:** This program includes both airborne contaminants and GHGs, and is effectively the same as Environment Canada's program but at the provincial level. We report GHGs and Part 4 contaminants (see above) for downtown as required, and voluntarily report these for Macdonald campus.

- **Inventaire des sources fixes d'émissions atmosphériques:** This municipal program is managed by the Ville de Montreal and includes our downtown and Macdonald campuses. Reporting is therefore mandatory and includes the volume of fossil fuels consumed at each campus.

- **Relevé énergétique du réseau universitaire:** This program, managed by the Ministère de l'Enseignement supérieur du Québec is mandatory for all university-owned buildings and includes all sources of energy used in those buildings.

- **STARS:** The Association for the Advancement of Sustainability in Higher Education's Sustainability Tracking, Assessment & Rating System is a voluntary self-reporting framework for colleges and universities. McGill currently has a Gold rating, and committed to achieving Platinum by 2030.

B. Compliance with the Greenhouse Gas Protocol

This GHG inventory was compiled and written following the guidelines of the World Business Council for Sustainable Development (WBCSD) and World Resources Institute's (WRI) "Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard" (2004). This standard, considered international best practice for organizational GHG accounting, is articulated around the following principles:

- **Relevance:** McGill's GHG inventory appropriately reflects the emissions of the University and was compiled in the spirit of serving decision-makers, both internal and external to McGill.

- **Completeness:** All material emission sources and activities within the chosen boundary are accounted for and reported, and any exclusions are disclosed and justified.

- **Consistency:** Consistent methodologies are used for meaningful comparisons of emissions over time. Changes to data, inventory boundary, methods, or any relevant factors is transparently documented.

- **Transparency:** All relevant issues are addressed in a coherent manner based on a clear audit trail. Any relevant assumptions are disclosed and appropriate references to the accounting and calculation methodologies and data sources used are made.

- **Accuracy:** Quantification of GHG emissions is systematically neither over nor under actual emissions and uncertainties have been reduced as far as practicable. The achieved level of accuracy should enable decision-making with reasonable assurance as to the integrity of the reported information.

McGill's 2017 GHG inventory was conducted using the location-based Scope 2 methodology detailed within the GHG Protocol Scope 2 Guidance: An amendment to the GHG Protocol Corporate Standard.

C. Description of the Organization

McGill is one of Canada's leading-edge research universities located in Montréal, Québec. The University was founded in 1821 and has grown into a world-class research institution. McGill offers more than 300 academic programs through 11 faculties and schools. Student enrollment for FY2017 was over 30,000 full-time equivalents and the University employed more than 12,000 faculty and staff, part time and full time. As of February 2018, the University's endowment was $1.634[1] billion and the budget for the financial year ending April 30, 2017 was $1.264 billion.[2]

McGill owns and operates over 200 buildings located on three main campuses on the island of Montréal in Québec: the Downtown Campus in downtown Montréal, the Macdonald Campus in Sainte-Anne-de-Bellevue, and the Gault Nature Reserve in Mont-Saint-Hilaire. The University also owns and operates several research stations both in Canada and abroad. The Bellairs Research Institute in Barbados is the largest such research station, but others include the McGill Arctic Research Station (MARS) and the McGill Sub-Arctic Research Station (M-SARS).

2. Scope of the Inventory

A. Reporting Period

This assessment report details the scope, data and results from McGill University's GHG inventory for calendar year 2017, from January 1 – December 31, 2017.

Reasonable effort was made to include data specific to this period. In some cases, due to consumption and billing periods, data delays, or timeframes for existing data tracking systems, data has been included for a different yearly period. Over consecutive assessments, we ensure that all activity data is captured and included. Importantly, if facilities or other assets are sold or relinquished, all activity data up to the date of transfer of ownership or retirement is included in the inventory for which data is available.

B. Greenhouse Gases and Global Warming Potentials

As required by best practice in organizational GHG accounting and the chosen WBCSD/WRI GHG Protocol, all seven Kyoto Protocol greenhouse gases have been included where applicable and material. Global warming potentials (GWPs) are factors describing the radiative forcing impact of one unit of a specific greenhouse gas (e.g. methane) relative to one unit of carbon dioxide. They are used in GHG accounting to convert individual greenhouse gas emissions totals to a single standardized unit useful for comparison – carbon dioxide equivalent, or CO_2e.

1 https://www.mcgill.ca/boardofgovernors/files/boardofgovernors/17._gd17-61_finance_committee_report_.pdf p. 24; market value
2 https://www.mcgill.ca/vpadmin/files/vpadmin/auditedfinancialstatementsyearendedapril_2017_2018-01-10_0.pdf p 2

McGill applied 100-year GWPs without climate-carbon feedbacks to all emissions data in this inventory in order to calculate total emissions in tonnes carbon dioxide equivalent (tCO_2e). Global warming potential values were sourced from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5 2013), the most recent IPCC report available at the time of assessment. The Kyoto Protocol GHGs (or categories of GHGs) and their respective GWPs are listed in the table below.

Greenhouse Gas	Chemical Formula	100-Year GWP
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265
Hydrofluorocarbons (HFCs)	Various	Various
Perfluorocarbons (PFCs)	Various	Various
Nitrogen trifluoride	NF_3	16,100
Sulphur hexafluoride	SF_6	23,500

Table 1 – Kyoto Protocol GHGs and GWPs, IPCC 2013

C. Change in Scope and Methodology

For the 2016 and 2017 inventories, which were conducted concurrently, a few significant expansions to the organizational and operational boundaries occurred and several methodologies were updated. In line with best practice accounting, the 2015 inventory was also updated to ensure consistency and comparability between these inventories. We provide a brief summary of these updates below.

Organizational Boundary

McGill University chose to include a number of facilities that were previously excluded from the scope of the inventory. For the most part, these facilities were previously excluded because they were considered to be immaterial, weren't under our operational control, or details regarding ownership and control were unavailable. We have now chosen to go beyond what is required per best practice by including a number of buildings over which we do not have operational control in our Scope 3 emissions, and have also estimated data for a few smaller research stations and facilities. Research facilities now included in the updated scope are the McGill Sub-Arctic Research Station (M-SARS) and energy consumption from the CLUMEQ super-computer shared with the École de technologie supérieure (ETS). We have included office space at 1010 Sherbrooke and 680 Sherbrooke, the Dentistry Clinic at 2001 McGill College, and a number of cottages and small residences rented out to non-student individuals at Macdonald Campus and downtown. We have also revised operational control details for some shared buildings to perceive full operational control, and have updated our share of energy consumption and resulting emissions.

Operational Boundary

The same set of emission sources that was included in the original 2015 inventory is included for 2016 and 2017 as well. We have adjusted the scope of certain energy sources – specifically distributed steam, hot water and chilled water – to align with updated operational control details and with best practice. Lastly, we were able to acquire fertilizer data for the Horticulture Centre and Lods Research Centre in addition to the Macdonald farm, and can now provide a complete picture for this activity.

Methodology

We chose to update the global warming potentials (GWPs) applied in the 2016 and 2017 inventory to those detailed in the IPCC's 5th Assessment Report. Per best practice, this required a re-calculation of emissions for our 2015 inventory as well, which was previously calculated using GWPs from the IPCC's 4th Assessment Report. At the same time, several emission factors related to vehicles were updated for all three inventories.

D. Organizational Boundary

This inventory follows the "operational control" consolidation approach of the GHG Protocol. Under this approach, McGill is required to account for 100% of the emissions from operations, facilities and sources over which it has operational control and is not required to account for GHG emissions from operations in which it owns an interest but over which it has no operational control.

We have chosen to include emissions from energy consumption in some buildings over which we do not have operational control within our Scope 3 emissions, going beyond the requirements of the chosen Protocol. Guidance from "Categorizing GHG Emissions Associated with Leased Assets: Appendix F to the GHG Protocol Corporate Accounting and Reporting Standard" (2006) was used for decision-making on the scope of energy emissions in these cases. The below section provides a summary of unique cases; for all solely owned buildings with operational control, we have included relevant emissions as Scope 1 and 2.

- **Buildings no longer under McGill ownership or control:** Any such building is not included in the scope of the inventory.
  - Beatty Hall: Sold in 2016
  - Saint Urbain 3626: Sold in 2016; electricity data included in the 2017 inventory for the final months of electricity invoices (which were not available at the time of the 2016 inventory).

- **Buildings owned by McGill with emphyteutic leases:** Where McGill is a lessor and the lease is emphyteutic, McGill does not have operational control and we have not included these emissions in the inventory. For all other buildings not listed below where McGill is the lessor, we perceive that we do have operational control and have included energy emissions as Scope 1 or 2.
  - McCord Museum, University 3605 – 3621, Redpath Street Properties: emissions not included in inventory scope.

- **Buildings co-owned or jointly managed:** We share, or previously shared, ownership or administration of a couple buildings with other organizations.
  - The Neuro: McGill owns the building and shares administration with the MUHC. We perceive operational control due to our current responsibility for the operations, maintenance and upgrades to the building's HVAC systems. All energy consumption is therefore categorized Scope 1 or 2 as relevant.
  - Sherbrooke 688: Co-owned with Industrielle Alliance (IA) up to July 31, 2017. From January 1 – July 31, 2017, IA had full operational control and emissions from energy consumption were included under Scope 3. From August 1, 2017, McGill took over full ownership and operational control and energy emissions are now categorized as Scope 1 and 2 as relevant..
  - Stewart Athletic Complex: McGill co-owns the building with John Abbott College. We perceive operational control since we are responsible for the operation and maintenance of the energy systems, so energy consumption is categorized as Scope 1 or 2 as relevant.

- **Buildings where McGill is a lessee without operational control:** For a number of locations, McGill leases or shares space but does not have operational control. Specifically, in these instances, we are unable to make any modifications to the building or energy systems and are not responsible for the operations or maintenance of these systems. Per Appendix F, a perceived lack of operational control exists and relevant emissions are not Scope 1 or 2. We have categorized the relevant energy emissions as Scope 3 and chosen to include these within the scope of our inventory.
  - Aima Inc., Cote de Neiges 5858, de Maisonneuve West 4920, the ETS-CLUMEQ computer, McGill College 2001, Peel 1555, Sherbrooke 550, Sherbrooke 680, Sherbrooke 1010, UQAM Pavillion des Sciences, Villa Burland.

- **Buildings where McGill is a lessee with operational control:** Per Appendix F, we perceive full operational control and have categorized energy consumption as Scope 1 or 2, as relevant.
  - Parc Avenue 3575.

E. Operational Boundary

Greenhouse gas emissions are broken down into three categories known as "scopes" that help delineate direct and indirect emission sources and avoid double counting between organizations, particularly at the level of national reporting. The WBCSD/WRI GHG Protocol requires the inclusion of all material Scope 1 and Scope 2 emissions because an organization has the most ownership and control over these activities. Scope 3 emission sources are optional under this Protocol, though best practice encourages organizations to include Scope 3 emissions sources that are critical to their business activities.

- **Scope 1 emissions:** direct emissions from sources owned or controlled by McGill
- **Scope 2 emissions:** energy indirect emissions from the consumption of purchased grid electricity and other similarly distributed energy types such as steam, hot water and chilled water
- **Scope 3 emissions:** other indirect emissions

Typically, the decision to include Scope 3 emission sources is based on a value chain analysis to determine their relevance and materiality. Relevant emissions are defined by McGill as: large, or believed to be so, relative to Scope 1 and 2 emissions; contributing to McGill's emissions and climate risk exposure; deemed critical by key stakeholders; and showing potential for reduction through measures that could be undertaken by McGill. As such, McGill's GHG inventory includes:

- **Scope 1 emissions:** All Scope 1 emissions within the organizational boundaries defined above with the exception of process gases generated by chemicals used for, and by-products generated by, research experiments. The reason for this exclusion is threefold:
    - Though McGill has a central chemical inventory management system, it isn't consistently used by the research community and data is therefore incomplete
    - Due to the extremely diverse nature of research happening on campus, it is virtually impossible to account for all the types of by-products generated during these experiments
    - Greenhouse gas emissions generated by experiments are deemed minimal with respect to total institutional Scope 1 and Scope 2 emissions

- **Scope 2 emissions:** All Scope 2 emissions within the organizational boundaries defined above.

- **Scope 3 emissions:** Scope 3 emissions deemed to be relevant as defined above. For the moment, the inclusion of relevant scope 3 emission sources has been decided in conjunction with key stakeholders based on activities that are believed to have the highest greenhouse gas impact and that are most relevant to the University's mission.
    - As such, the following activities and resulting Scope 3 emissions are included in the CY2017 inventory:
        - Electricity, natural gas and heating oil consumption for the Scope 3 cases outlined in section D above
        - Student, faculty and staff commuting
        - Directly-financed University-related air travel
        - Travel by the University's sport teams
        - Travel by the Macdonald Shuttle bus
        - Water supply & treatment
        - Power transmission & distribution (T&D) losses occurring between the production sites and McGill facilities
    - In CY2017, the University worked with just under 10,000 suppliers and purchased over $400 million worth of goods and services. Procurement Services estimates that around 4,100 faculty and staff can make purchases. This makes a thorough analysis of McGill's value chain quite challenging though it is on the roadmap of Procurement Services for the years to come.

- **Other emissions reported separately:** Emissions from refrigerants not covered by the Kyoto Protocol and avoided emissions from solid waste disposal are reported separately.
    - o No emission factor is readily available to calculate absolute emissions occurring from the management of solid waste; however, tools allow for an estimate of greenhouse gas reductions achieved by McGill through its waste management and diversion program.

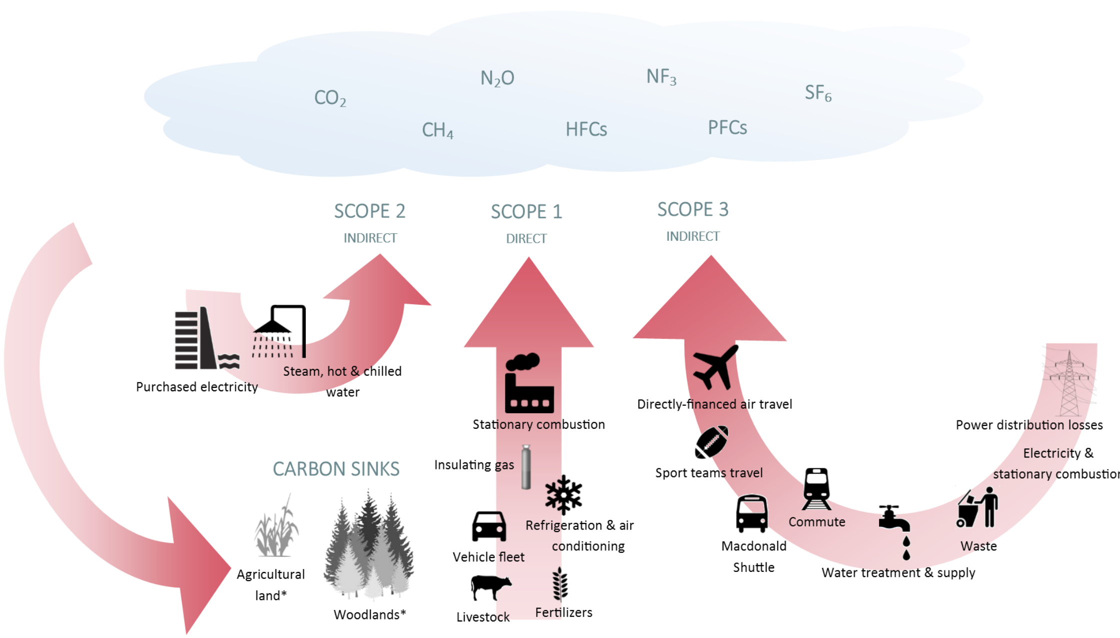


Figure 1 - Overview of Emissions Included in McGill's 2017 Inventory by Scope

** Agricultural land and woodlands can either be sources of emissions or carbon sinks depending on land management practices.*

Detailed List of Activities Included in the Inventory

The below table details the activities included in the CY2017 inventory. The "Exclusions" column of this table focuses on exclusions within the identified activity; activities not included in the inventory scope are detailed in Table 4 below.

Activity	Scope	Fuel(s) or Gas	Exclusions	Rationale for exclusion
On-site stationary combustion – large boilers	1	Natural gas, heating oil	None	N/A
On-site stationary combustion – small boilers	1	Natural gas, heating oil, propane	None	N/A
On-site stationary combustion – emergency power generators	1	Diesel, natural gas	Small research stations	No data available and emissions deemed minimal
Uncontrolled leaks of refrigerants	1	Various refrigerants	1) Stand-alone systems from some buildings 2) A/C window units 3) Refrigerants not covered by Kyoto Protocol	1) Data unavailable 2) No inventory of A/C window units 3) Reported separately
Uncontrolled leaks of electrical insulating gas	1	SF_6	None	No data available
On-site combustion – mobile equipment (grounds & landscaping)	1	Diesel	None	N/A
McGill-owned fleet of vehicles	1	Gasoline, diesel	None	N/A
Fertilizers	1	--	None	N/A
Livestock	1	--	None	N/A
Purchased electricity	2	Electricity	Small research stations	No data available and emissions deemed minimal
Purchased steam	2	Steam	None	N/A
Purchased hot and chilled water	2	Water	None	N/A
Directly-financed air travel	3	--	None	N/A
Commuting	3	--	Commute to and from smaller campuses and research stations	No data available
Sport teams travel	3	--	Main varsity teams only	Other teams travel very little & emissions are deemed minimal
Water supply & treatment	3	--	None	N/A
Macdonald Shuttle	3	Diesel	None	N/A
Power distribution losses	3	Electricity	Small research stations	No data available and emissions deemed minimal

Table 2 - List of Activities Included in Inventory

List of Activities Reported Separately

Activity	Rationale for separate reporting	Exclusions	Rationale for exclusion
Solid waste (domestic waste, hazardous waste, and construction waste)	Available tools don't quantify absolute emissions – which would require full life cycle analysis of all waste streams. Instead, this report evaluates reductions in GHG emissions achieved through McGill's waste management.	Waste from small research stations	No data available
Refrigerants not regulated by the Kyoto Protocol	As per the GHG Protocol standard.	1) Stand-alone systems from some buildings 2) A/C window units	1) Data unavailable 2) No inventory of A/C units on campus
Carbon sinks (Morgan Arboretum, Gault Nature Reserve, Macdonald Campus Farm)	As per the GHG Protocol standard. Note that this information will be included in future reports once ongoing research to assess the carbon sequestration potential of McGill's forests and agricultural land is completed.	N/A	N/A

Table 3 - List of Activities Reported Separately

List of Activities Excluded from the Inventory

Activity	Rationale for exclusion from inventory reporting
Research experiments	1) Incomplete data as to types and amounts of chemicals purchased 2) Calculating and/or monitoring types and amounts of experiment products and by-products unfeasible
Research animals	1) Data on types of animals and headcount is classified and unavailable 2) Given the types of research animals, direct emissions presumed negligible compared to already-quantified Scope 1 and 2 emissions
Directly-financed travel other than air travel (e.g. train, bus, car rentals and taxis, and trips by personal vehicle)	Information currently unavailable
Refrigerants, commuting, solid waste, water supply and water treatment for the Gault Nature Reserve and the Bellairs Research Institute	Amounts are negligible and data isn't readily available
Data pertaining to smaller offsite research stations	Information unavailable and/or hard to collect; energy for certain research stations has been included, such as the M-SARS location
Carbon sinks (Morgan Arboretum, Gault Nature Reserve, Macdonald Campus Farm)	No data. Fundamental research is underway to assess the carbon sequestration and/or emissions potential from woodlands and agricultural land. This information will be included in future reports.

Table 4 - List of Activities Excluded from Inventory

3. Calculation Methodology

A. Process Flow

The figure below outlines the process flow of the different steps of the greenhouse gas reporting process.

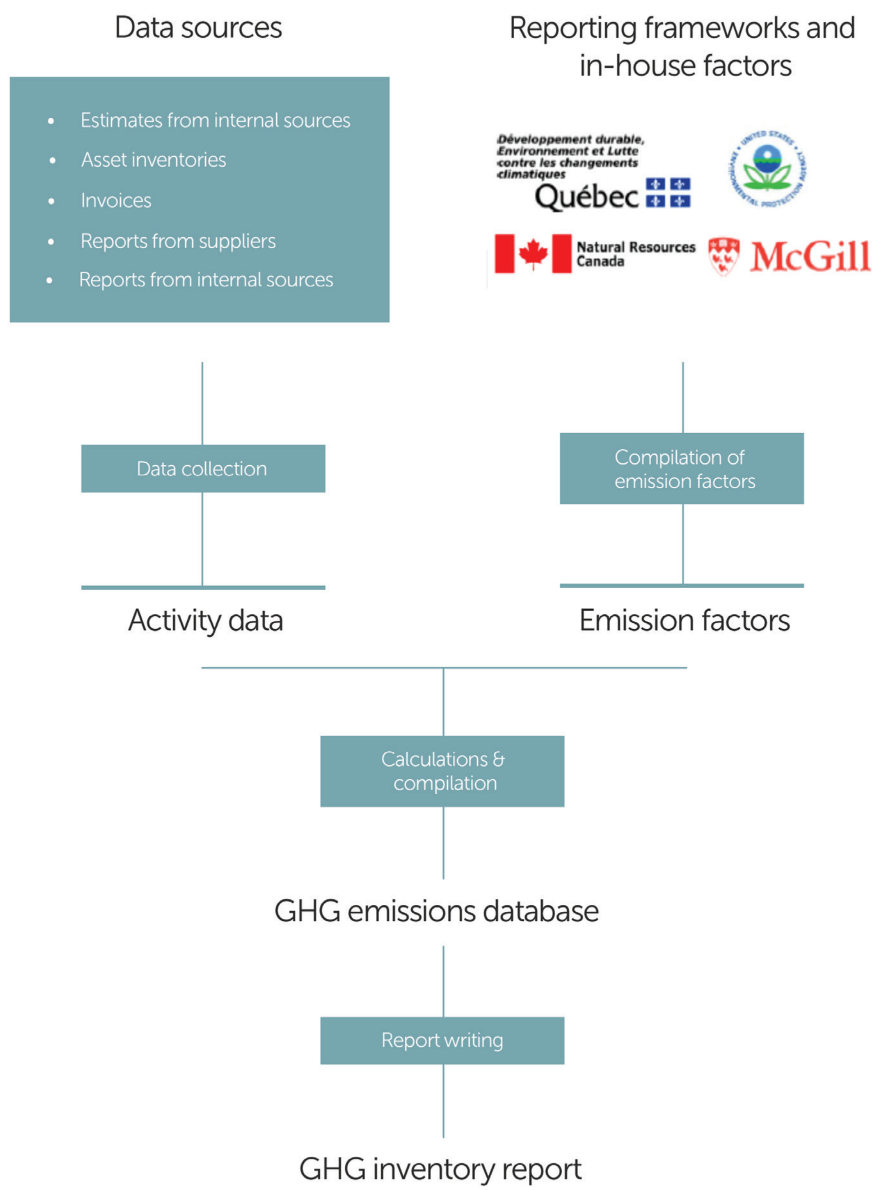


Figure 2 – McGill's Greenhouse Gas Reporting Process

B. Data Sources and Calculation Methods

The following table briefly outlines the calculation method used for each data source. Detailed calculation methodologies are included in the appendices to this report. There are several acronyms used in the below table:

- FAMIS: McGill University's Facilities Management and Space System
- MDDELCC: Ministère du Développement durable, de l'Environnement et de la Lute contre les changements climatiques du Québec
- NRCan: Natural Resources Canada
- UK BEIS: United Kingdom Department for Business, Energy and Industrial Strategy
- US EPA: United States Environmental Protection Agency

SCOPE 1

Activity	Data source	Calculation method	Source of emission factor
Generators, Downtown	Invoices collected by Facilities Accounting	Emission factor	MDDELCC
Generators, Macdonald	Invoices collected by Macdonald Operations	Emission factor	MDDELCC
Grounds, Downtown	Invoices collected by Facilities Accounting	Emission factor	MDDELCC
Heating oil, Downtown	Invoices collected by Facilities Accounting	Emission factor	MDDELCC
Heating oil, Macdonald	Invoices collected by Macdonald Operations	Emission factor	MDDELCC
Natural gas, Large boilers	Invoices collected by Utilities & Energy Mgmt.	Emission factor	MDDELCC
Natural gas, Small boilers	Invoices collected by Utilities & Energy Mgmt.	Emission factor	MDDELCC
Propane	Invoices collected by Macdonald Operations	Emission factor	MDDELCC
Purchased steam	Meter data read by Utilities & Energy Mgmt.	Estimate of production + generation efficiency Emission factor method	MDDELCC
Vehicles & Grounds, Macdonald	Report from Supervisor of Property and Maintenance based on vehicle logs	Emission factor	MDDELCC, NRCan
Vehicles, Downtown	Report from fleet management software from Parking and Transportation Services	Emission factor	MDDELCC, NRCan
Vehicles, Research	List of assets from Risk Management & Insurance unit	Emission factor	MDDELCC, NRCan
Fertilizers, Macdonald, Lods and Horticulture Centre	Volumes and types spread according to Chief Agronomy Technicians	Emission factor	US EPA
Livestock	Estimate of headcount and manure management by Farm Manager	Emission factor	NRCan
Refrigerants, Downtown	List of assets from Downtown Operations	Estimate of leak rate Emission factor method	MDDELCC IPCC
Refrigerants, Macdonald	List of assets from Macdonald Operations	Estimate of leak rate Emission factor method	MDDELCC IPCC
Insulating gas	List of assets from FAMIS	Emission factor	MDDELCC

SCOPE 2

Activity	Data source	Calculation method	Source of emission factor
Electricity	Annual report to the Ministry of Higher Education compiled by Facilities Accounting	Emission factor	NRCan UNEP/DTU
Electricity, other SHHS buildings	Invoices compiled by SHHS Facilities – Sustainability Intern	Emission factor	NRCan

SCOPE 3

Activity	Data source	Calculation method	Source of emission factor
Air travel, directly funded	Report from McGill's Travel Helpdesk based on reimbursement requests Financial services	Emission factors	UK BEIS
Commuting	2011 McGill Transportation Survey report (TRAM)	Survey results corrected to student and employee populations	In-house (McGill)
Solid waste: Composting, Downtown	Reports from service supplier	Calculate reductions from reference scenario	US EPA Warm Model
Solid waste: Composting, Macdonald	Estimates from the Supervisor of Property Maintenance	Calculate reductions from reference scenario	US EPA Warm Model
Solid waste: Construction, renovation and demolition waste	Estimates from the Senior Manager of Design Services	Calculate reductions from reference scenario	US EPA Warm Model
Solid waste: Domestic waste & recycling, Downtown	Report from service supplier	Calculate reductions from reference scenario	US EPA Warm Model
Solid waste: Domestic waste & recycling, Macdonald	Report from service supplier	Calculate reductions from reference scenario	US EPA Warm Model
Hazardous waste	Annual report from Hazardous Waste Management	Calculate reductions from reference scenario	US EPA Warm Model
Macdonald Shuttle	Report from service provider	Emission factor	US EPA
Sport teams travel	Report from student project	Emission factor	UK BEIS; US EPA
Water supply and treatment	Water audits from Utilities & Energy Mgmt.	Emission factor	In-house (McGill)

Table 5 - Data Sources and Calculation Methods

C. Emission Factors

Emissions factors used in the calculation of GHG emissions are presented in the below table. Emission factors were sourced from reputable third-party organizations, typically government reports, or have been developed in-house specific to McGill's own systems.

Fuel or activity	Organization	Source of emission factor
Air travel – short, medium and long haul (average class)	UK BEIS	2017 Government GHG Conversion Factors for Company Reporting, Air Travel
Electricity (Québec)	NRCan	National Inventory Report 1990-2016, Part 3, Table A13-6
Electricity (Barbados)	UNEP/DTU	Analysis of Grid Emission Factors for the Electricity Sector in Caribbean Countries, Annex 4
Fertilizers (various)	US EPA	Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors, Ch. 14.1
Diesel – stationary combustion	MDDELCC	LRQ Q-2, r. 15, Table 1-3, Diesel
Diesel – mobile equipment, on-road	MDDELCC	LRQ Q-2, r. 15, Table 27-1, Diesel vehicle
Diesel – mobile equipment, off-road	NRCan	National Inventory Report 1990 – 2016, Part 2, Table A6-12
Gasoline – mobile equipment	MDDELCC	LRQ Q-2, r. 15, Table 27-1, Gasoline vehicle
Propane – mobile equipment	MDDELCC	LRQ Q-2, r. 15, Table 27-1, Propane vehicle
Heating oil	MDDELCC	LRQ Q-2, r. 15, Table 1-3, Light fuel oil, Institutional
Sulphur hexafluoride (SF6)	MDDELCC	LRQ Q-2, r. 15, Schedule A.1
Livestock (various)	NRCan	National Inventory Report 1990-2010, Annex 3
Natural gas – stationary combustion	MDDELCC	National Inventory Report 1990-2016, Part 2, Tables A6-1+2
Propane	MDDELCC	LRQ Q-2, r. 15, Table 1-3, Propane – All other uses
Refrigerants (various)	MDDELCC	LRQ Q-2, r. 15, Schedule A.1
Intercity bus	US EPA	GHG Emission Factors Hub. Center for Corporate Climate Leadership, Table 8, bus
Taxi	US EPA	GHG Emission Factors Hub. Center for Corporate Climate Leadership, Table 8, passenger car
Public transit	US EPA	GHG Emission Factors Hub. Center for Corporate Climate Leadership, Table 8, transit rail
Water supply	McGill	Fall 2015 ENV-401 student project. Emission factors were calculated from information collected from the City of Montréal, City of Sainte-Anne-de-Bellevue, and Montréal Wastewater Treatment Plant.
Water treatment	McGill	

Table 6 - Emission Factors

D. Key Assumptions

Complete, primary data was used wherever possible. For certain emissions sources, data was either unavailable or incomplete, and assumptions and modelling were necessary to conservatively estimate associated emissions.

Stationary energy consumption

- For all buildings with missing energy data (typically smaller buildings or buildings where McGill is the lessee or lessor to a non-student individual), electricity consumption was estimated using an annual energy intensity factor (GJ/m^2) for base load electricity, specific to the Commercial and Institutional sector in Québec (Natural Resources Canada).

- For all buildings with missing energy data, heating and hot water energy consumption was similarly estimated, using an annual energy intensity factor (GJ/m^2) for space heating and domestic hot water in the same sector and location (Natural Resources Canada). In buildings where the energy source of heating was unknown, natural gas was assumed as a conservative measure. In order to convert annual energy intensity to fuel combustion, estimated average system efficiencies were applied per energy source (100% for electricity, 80% for natural gas, 75% for propane and 75% for heating oil).

- Steam consumption for the RVH was calculated using two methodologies. For months in 2017 for which data was available, energy was calculated using the same distribution efficiency (90%) and combustion efficiency ($29 lb/m^3$) as for McGill's downtown steam distribution. Where data for the RVH was not fully available due to billing cycles, readings for May 2016 – April 2017 taken from McGill's meters in the MUHC were normalized to the January – December 2017 period using heating degree days (18°C basis); the same efficiencies were then applied.

- Heating hot water consumption for the Neuro was estimated using readings for May 2016 – April 2017 taken from McGill's meters in the RVH. This data was normalized to the January – December 2017 period using heating degree days (18°C basis). Domestic hot water consumption for the Neuro was estimated by professionals and is assumed to be constant from year to year.

- Chilled water consumption from Second Investment was calculated using a coefficient of performance of 4.0 to determine the electricity consumption corresponding to monthly chilled water invoices.

- Hot water consumption from Second Investment was calculated using an overall efficiency of 90% to determine the volume of natural gas corresponding to monthly hot water invoices.

- Energy consumption from JAC was unavailable at the time of inventory. Electricity consumption was estimated using an average of the previous three years, while natural gas consumption was estimated using an estimate of heating requirements made by consultants for the building and converted to volume assuming an overall efficiency of 90%.

Vehicle fleet

- Fuel consumption data for vehicles and mobile equipment at Macdonald Campus was available per vehicle, while fuel consumption data for the majority of vehicles and mobile equipment at the Downtown Campus was available aggregated by fuel type (gasoline vs. diesel) in ARI reports. ARI reports aggregate all non-diesel fuels (e.g. ethanol, methanol) into the gasoline total.

- Actual fuel consumption data for a few vans and light duty vehicles as well as a number of specialized vehicles downtown – including ATVs, boats, snowmobiles, tractors, forklifts and seadoos – was not available. Fuel consumption for the vans and light duty vehicles were estimated using average fuel efficiency values per fuel type sourced from the ARI report. Fuel consumption for the specialized vehicles was estimated using researched fuel efficiency and usage metrics specific to each vehicle type.

- All vehicles and mobile equipment were categorized as either "on-road" (e.g. cars, pickup trucks, vans, SUVs and maintenance vehicles) or "off-road" (e.g. tractors, ATVs, forklifts, boats, seadoos and small machinery) to allow the application of emission factors specific to off-road (EC 2017) and on-road (MDDELCC 2018) vehicles. All vehicles included in the ARI fuel reports were considered "on-road".

Process gases

- The amount of refrigerant used and lost per system is not directly available. Refrigerant gas loss for various buildings and systems was estimated following the calculation of the total cooling capacity per system (in BTU/hr or tons of refrigeration) using LEED's methodology and the below assumptions and default values:
    - 2% leakage rate (LEED default value)
    - 10 years equipment lifetime (LEED default value)
    - 10% end-of-life refrigerant loss (LEED default value)
    - Refrigerant charge of 5.0 lbm per ton of cooling

- Using the above data and methodology, the lifetime emissions of the system were calculated and divided by the expected equipment lifetime to estimate annual leakage.

- For refrigeration equipment where the refrigerant gas used was unknown, the most commonly used refrigerant was assumed (R-134a). If no cooling capacity data was available for a piece of equipment, it was not included.

Agriculture and Livestock

- Headcount data and manure management details (e.g. % liquid systems vs. % solid storage & dry lot vs. % pasture, range & paddock vs. % other) was provided for the Macdonald farm per species of livestock.

- Fertilizer data was provided as quantity spread per fertilizer type for the Macdonald farm, Lods Re search Centre and Horticultural Centre.

- The EPA's methodology [3] for calculating nitrous oxide emissions from commercial fertilizer was applied to calculate nitrogen content per fertilizer type and resulting emissions.

Commuting

- In their "Transportation Survey Report" (2011), the researchers for Transportation Research at McGill (TRAM) conducted a survey of our community's mobility and commuting habits and calculated average emission factors for annual commuting emissions per student and per staff.

- These emission factors were applied to FY2017 headcount data for students and staff. Note that the 2013 TRAM survey did not include the objective to calculate environmental impacts from commuting, so TRAM 2011 results were applied.

Air travel

- Air travel data was sourced from McGill's expense reporting system, which does not currently request details related to flight origin (only a destination field is included), route, multiple legs or class of travel. The below assumptions were made to account for these gaps in data.

- Flight class was assumed "average" for all flights in absence of information.

- All flights were assumed direct, unless otherwise stated in provided information, in absence of transparency into flight route.

3 https://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s01.pdf

- All flights were assumed to originate from Montreal's Pierre Elliot Trudeau airport (YUL) and return to this airport unless otherwise stated in the "Destination City" data.

- For "Destination City" entries with multiple destinations listed, flight route was assumed to proceed in the order entered on the expense report.

- For "Destination City" entries that were stated as a whole country or province/state/region (e.g. "France" or "Florida") and not a specific city, either the capital city or the largest nearby city with an international airport was used, as appropriate.

- Unless stated in the "Destination City" information (e.g. JFK, LHR), airports were determined using the city in the "Destination City" entry and the "TravelMath – nearest major airport" function. The closest international airport was selected as a default unless the closest international airport was a) >400km away or b) located in another country. In these cases, the closest regional airport may have been used.

- A large number of flights in the Canada data set were labelled with "Destination City" Montreal (various spellings), and several flights in all three data sets (Canada, USA and International) had non-usable "Destination City" entries (e.g. "Various cities", "Aug 26"). In absence of usable flight data, a median $/mile was calculated from all usable data per data set and applied to estimate total distance (and haul category) from the cost data for these rows.

Macdonald shuttle

- Total distance travelled in passenger-km was calculated using ridership data from seasonal reports and the route-specific distance between the downtown and Macdonald campuses.

Sports team travel

- Varsity team travel data was collected and calculated as part of a research project during summer 2016 using data from FY2016. This data, in the form of total passenger-km per travel mode, was applied to the CY2017 inventory as well.

- A new data collection process for varsity team travel has been established with the Athletics department to facilitate accurate team travel data tracking for future inventories.

Water supply and treatment

- Annual water input data was available for approximately 54% of Downtown campus buildings and 61% of Macdonald campus buildings (by area). Consumption for the remaining buildings was estimated using average water use intensity factors (m^3/year/m^2) specific to each campus. In order to account for water savings achieved over the course of 2016 and 2017, consumption associated with estimated savings was removed from the Downtown campus' consumption total.

- Water volume attributed to process losses was aggregated with estimated water volume lost to leakage for each campus. Both these values were sourced from an ENV-401 student group's research, conducted specifically for this purpose. Total water output volume was then calculated for each campus and assumed equivalent to wastewater treated.

Transmission & distribution (T&D) losses

- Electricity lost to transmission & distribution was estimated using average T&D loss factors sourced from Hydro Québec (Downtown, Macdonald and Gault campuses) and Barbados Light & Power (Bellairs campus), applied to total campus consumption.

4. Results

A. 2017 GHG Emissions

Total emissions for the chosen scope for calendar year 2017 were 56,004 tCO_2e. It is useful to show a breakdown of our emissions by both scope and activity because the identification of large emission sources allows us to target these areas for emission reduction initiatives and enables us to track our progress for each emission source over time.

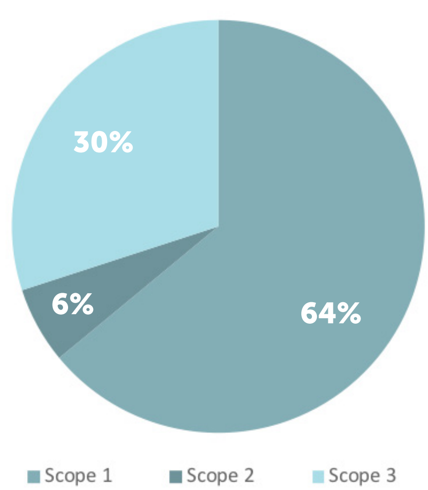


Figure 3a - Emissions breakdown by scope

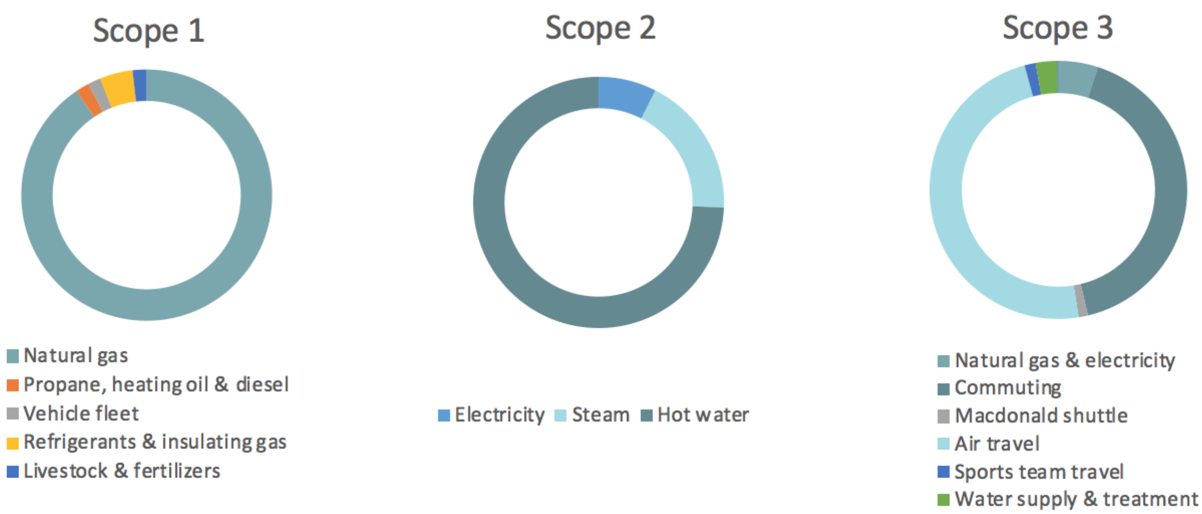


Figure 3b – Emissions breakdown by scope and activity

Greenhouse Gas	Emissions (tGHG)	Emissions (tCO_2e)
Carbon dioxide (CO_2)	53,517	53,517
Methane (CH_4)	20	562
Nitrous oxide (N_2O)	1.5	411
Refrigerant R134a	1.0	1,295
Refrigerant R125	0.04	143
Refrigerant R32	0.04	30
Sulphur hexafluoride (SF_6)	0.002	47

Note: For emission factors only available in units of CO_2e, emissions have been wholly attributed to CO_2 in the tGHG column

Table 7 – Emissions breakdown by greenhouse gas

Scope 1 sources contributed a significant share – 35,628 tCO_2e (64%) – of McGill's emissions. Natural gas consumed in our buildings, used for heating, cooling, and research activities, contributed 32,261 tCO_2e and accounted for the majority (91%) of Scope 1 emissions. Energy efficiency and reduction efforts across our campuses over the past decade have contributed to significant reductions already; to date, emissions from building energy use have decreased 36% since 1990. Continuing this trend will be critical to achieving carbon neutrality, which is one of the reasons that the 2016 – 2020 phase of McGill's Energy Management Plan (EMP)[4] includes a 64% energy GHG reduction target below 1990 by 2021. The EMP identifies several interventions for the next phase, including the deployment of smart grids downtown, heat recovery from the downtown powerhouse, and major HVAC upgrades to several buildings.

The figures below provide an overview of the energy generation mix of each Canadian province. Renewable energy dominates the generation mix in Québec, with 96% of our electricity generated from hydro and a further 3.5% derived from other renewable sources such as wind, tidal and solar. This creates an electricity generation intensity of only 1.1 gCO_2e/kWh, which is the lowest in Canada. For context, the Canadian average generation intensity is 150 gCO_2e/kWh and the generation intensity of Alberta, the most carbon intensive province, is 810 gCO_2e/kWh.

Due to both the low carbon intensity of Québec's electricity grid and ongoing electricity efficiency initiatives on our campuses, our Scope 2 sources – comprised of electricity consumption and other grid-distributed energy such as steam, hot water and chilled water – accounted for 3,630 tCO_2e – only 6.5% of the University's emissions – in 2017.

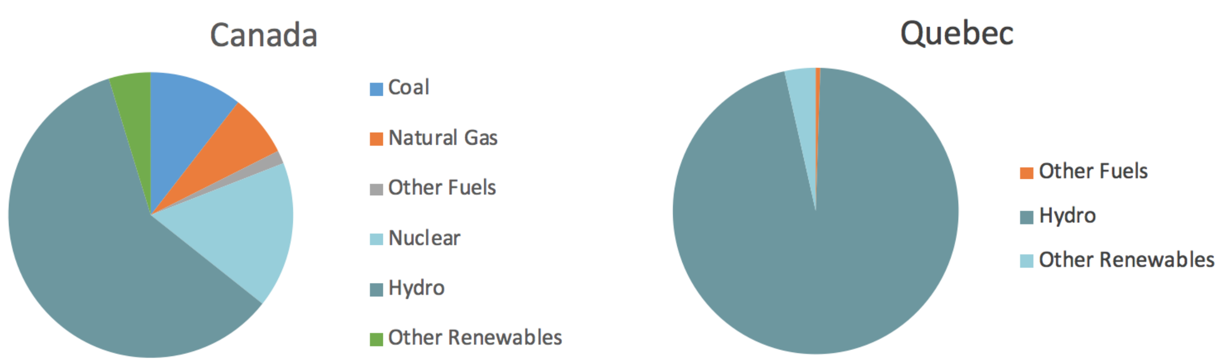


Figure 4a – Comparison of Energy (GWh) Used for Electricity Generation between Canada (average) and Quebec

4 https://www.mcgill.ca/facilities/utilities/energymanagement

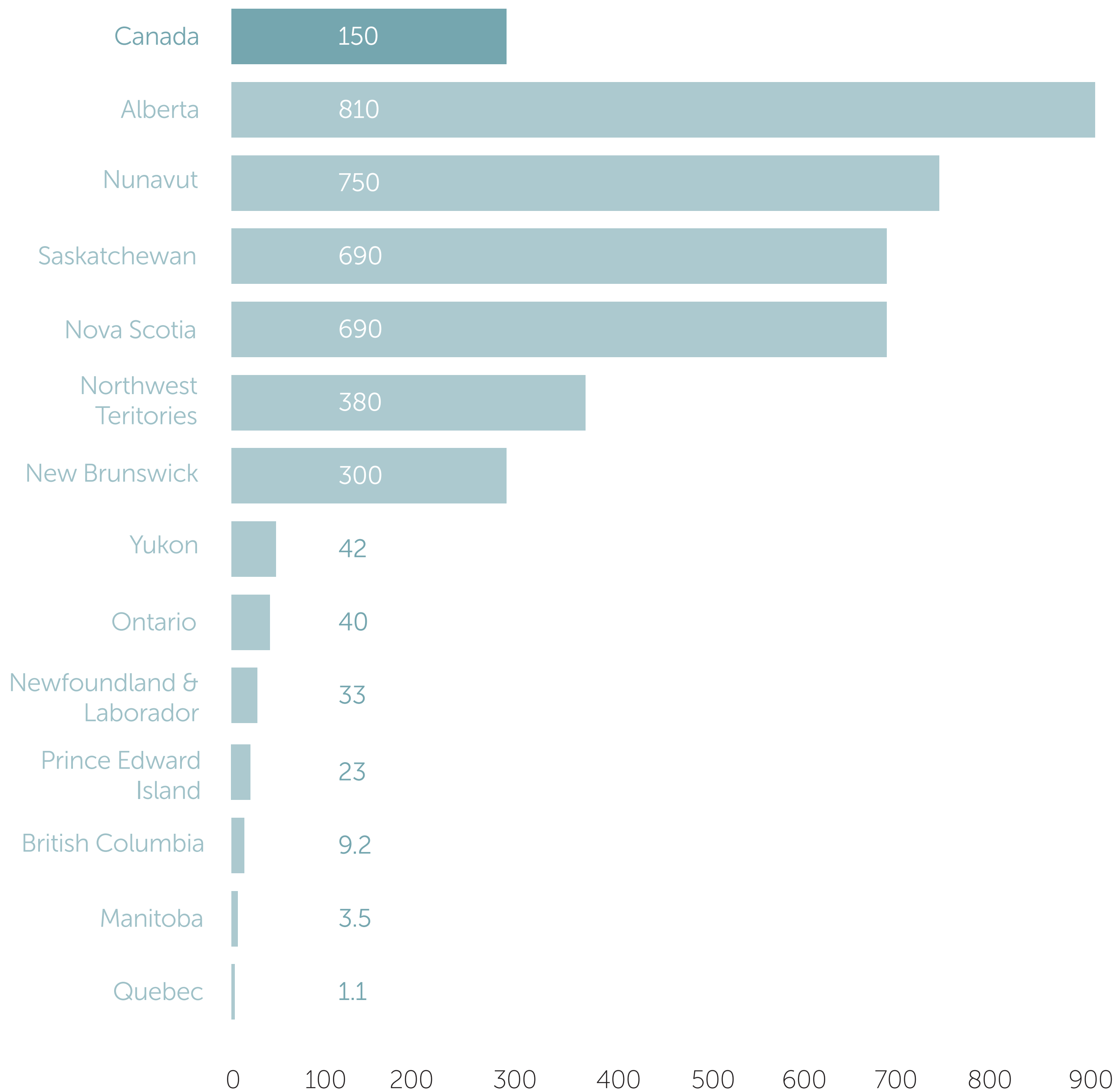


Figure 4b – Electricity Generation Intensity by Province (gCO_2e/kWh)

McGill's Scope 3 sources made up the remaining 30% of our footprint. It is worth noting that most of our Scope 3 emissions arise from travel. Directly financed air travel accounted for 14% of our total emissions in 2017 while mobility – commuting of our students, faculty and staff – contributed just over 12%. Together, these two sources make up 90% of our Scope 3 emissions.

The table below provides a detailed overview of McGill's emissions in 2017, broken down by scope and activity. In addition, the table displays the information outlined in Table 3 of this report – that is, information that needs to be presented separately from our GHG inventory according to best practice. Specifically, we show emissions that we avoided due to the diversion of our recycled and composted waste from landfill and emissions arising from the loss of refrigerants that are governed by the Montreal Protocol and not the Kyoto Protocol.

Inventory Category	Activity	Activity Level	Unit	Emissions (tCO_2e)	% of Total Emissions
Scope 1 (direct emissions)					
Stationary combustion	Natural gas	17,003,719	m^3	32,261	58%
	Propane	12,609	L	19	0.03%
	Heating oil	171,012	L	468	0.8%
	Diesel	48,706	L	137	0.2%
McGill-owned fleet of vehicles	Diesel vehicles	137,471	L	407	0.7%
	Gasoline vehicles	70,803	L	168	0.3%
	Propane vehicles	5,720	L	8.8	0.02%
Refrigerants & chemicals	Refrigerants	1,086	kg	1,468	2.6%
	Insulating gas	2	kg	47	0.08%
Agriculture	Livestock	6,762	heads	570	1.0%
	Fertilizers	59,384	kg	73	0.1%
Scope 1 (direct emissions) - Total				35,628	64%
Scope 2 (energy indirect emissions)					
Purchased energy	Electricity	179,478,655	kWh	273	0.5%
	Steam	347,171	m^3	659	1.2%
	Hot water	2,709,365	m^3	2,699	4.8%
	Chilled water	169,635	kWh	0.2	0.0003%
Scope 2 (energy indirect emissions) - Total				3,630	6.5%
Scope 3 (indirect emissions)					
Stationary combustion	Natural gas	429,634	m^3	815	1.5%
	Electricity	12,929,433	kWh	15	0.03%
Commuting	Faculty & staff	12,011	staff	4,608	8.2%
	Students	31,961	students	2,316	4.1%
Third-party fleet	Macdonald shuttle	5,746,932	pass-km	197	0.4%
Air travel	Directly-financed air travel	81,896,551	pass-km	8,087	14%
Sports team travel	Air	1,555,960	pass-km	153	0.3%
	Bus	2,288,485	pass-km	78	0.1%
	Public transit	189	pass-km	1.7	0.003%
	Taxi	88	km	0.002	0.000004%
Water	Supply	2,095,613	m^3	155	0.3%
	Treatment	1,292,186	m^3	299	0.5%
Energy losses	Transmission & distribution	14,429,447	kWh	21	0.04%
Scope 3 (indirect emissions) - Total				16,746	30%
Total Emissions				56,004	100%

Non-Inventory Category	Activity	Activity Level	Unit	Emissions (tCO_2e)	% of Total Emissions
Avoided emissions from waste management					
	Solid waste - recycling	288	tonnes	-840	-
	Solid waste - composting	328	tonnes	-180	-
Avoided emissions from waste management - Total				-1,020	
Refrigerants governed by Montreal Protocol					
	Refrigerants (e.g. R22)	214	kg	286	-

Table 8 – 2017 Greenhouse Gas Inventory

McGill University's GHG inventory includes activities taking place on all four of our campuses – Downtown, Macdonald, Gault and Bellairs. Aside from being in different cities or countries, our campuses also differ in their number and type of facilities, predominant energy sources & generation efficiencies, primary campus activities, and typical campus population. It is therefore worthwhile to split emissions arising from energy consumption for each campus. While we also have data for other emission sources split by campus – such as refrigerant gas loss, vehicle fleet and waste – we have focused on energy consumption because it comprises such a significant portion of the footprint at each campus.

Energy Consumption	Electricity (kWh)	Chilled Water (kWh-e)	Steam (m^3 of NG-e)	Hot Water (m^3 of NG-e)	Natural Gas (m^3)	Heating Oil (L)	Propane (L)	Diesel (L)
Total McGill								
Scope 1	0	0	0	0	17,003,719	171,012	12,609	35,681
Scope 2	179,478,655	169,635	347,171	1,422,470	0	0	0	0
Scope 3	12,929,433	0	0	0	429,634	0	0	0
Total	192,408,088	169,635	347,171	1,422,470	17,433,353	171,012	12,609	35,681
Per Campus								
Downtown Campus	167,119,425	169,635	347,171	1,407,832	15,700,058	0	0	32,674
Macdonald Campus	18,042,918	0	0	14,637	1,710,432	149,868	12,609	3,008
Gault Nature Reserve	469,680	0	0	0	0	21,144	0	0
Bellairs Institute	89,184	0	0	0	0	0	0	0
Other	6,686,880	0	0	0	22,863	0	0	0
Total	192,408,088	169,635	347,171	1,422,470	17,433,353	171,012	12,609	35,681

Table 9- Energy Consumption Per Campus by Energy Type

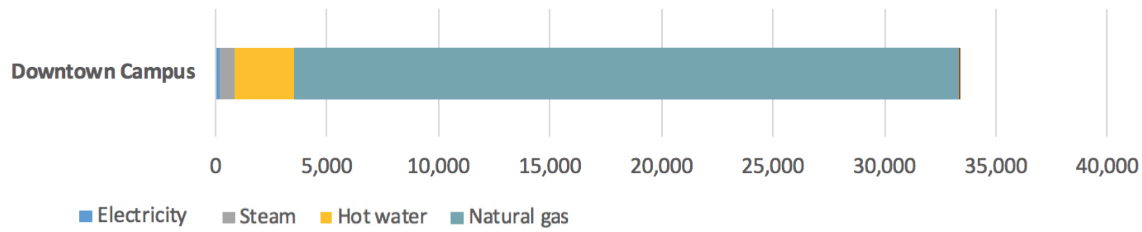


Figure 5a – Energy Emissions (tCO_2e) by McGill Campus: Downtown Campus

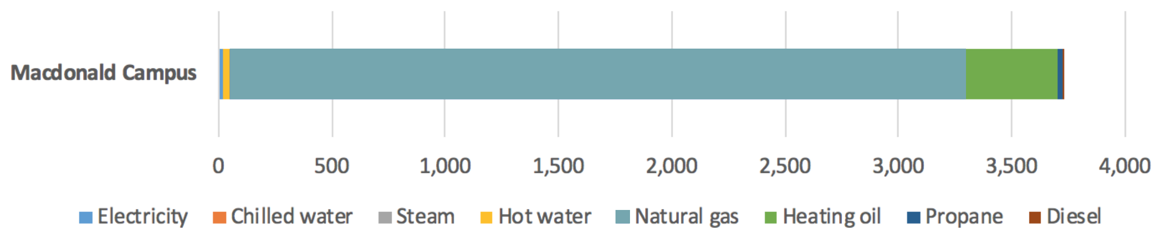


Figure 5b – Energy Emissions (tCO_2e) by McGill Campus: Macdonald Campus

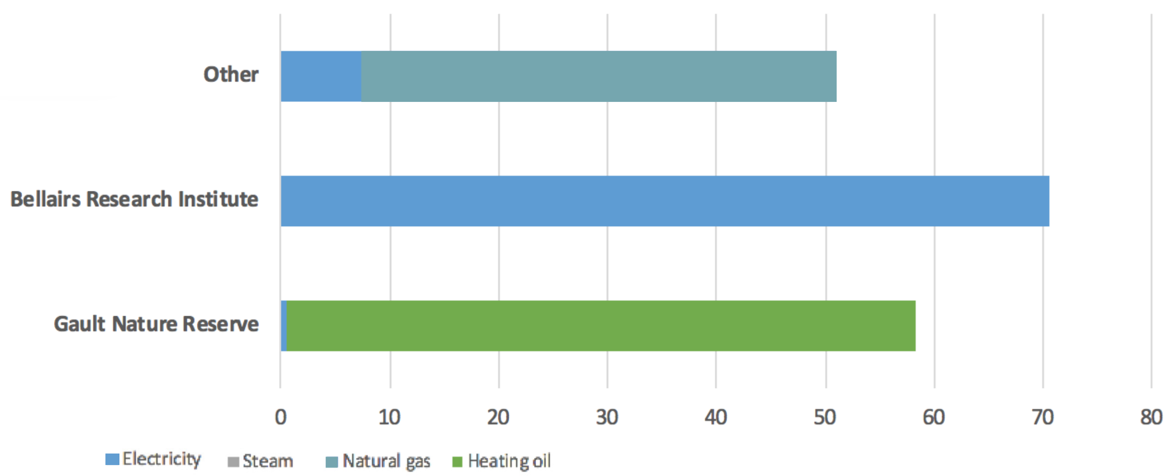


Figure 5c – Energy Emissions (tCO_2e) by McGill Campus: Other Campuses and Locations

Unsurprisingly, given the total number of buildings, campus populations, and higher proportion of energy-intensive research labs, energy consumption at the downtown campus is highest and accounts for 90% of McGill's total energy emissions. Starting with the 2018 inventory, we aim to provide GHG footprints specific to each campus for Scope 1 and 2 emission sources. Over time, we will work on improving data tracking systems in several key Scope 3 areas as well, such as air travel and commuting, to facilitate a campus breakdown for Scope 3 as well.

B. Comparison of Base Year and Current GHG Emissions

As required by the GHG Protocol, McGill must select an inventory base year for which verifiable data is available in order to track emissions over time. McGill's base year is 2015, chosen because: a) the 2015 inventory was the first to comply with the GHG Protocol; b) relatively complete data sets were available for all material emission sources and; c) the inventory was audited by McGill's internal audit team.

As noted in Section 2C, the 2015 inventory was re-calculated to align with the newly expanded inventory scope and applied methodologies. Total emissions for the updated 2015 inventory were 58,819 tCO_2e, which means that we realized emission reductions of 2,815 tCO_2e (-4.8%) between 2015 and 2017. Notably, McGill achieved emissions reductions across all three scopes. The most significant reductions occurred in our energy consumption, specifically natural gas (Scope 1 + 3 reductions: -2,257 tCO_2e), heating oil (-326 tCO_2e), steam (-293 tCO_2e), and hot water (-88 tCO_2e) consumption.

The below table provides a comparison of data and emissions between the updated 2015 inventory and the 2017 inventory.

Inventory Category	Activity	Emissions (tCO_2e) 2015	2017	Change (tCO_2e)	% Change
Scope 1 (direct emissions)					
Stationary combustion	Natural gas	34,334	32,261	-2,073	-6.0%
	Propane	26	19	-7.0	-26%
	Heating oil	794	468	-326	-41%
	Diesel	98	137	39	40%
McGill-owned fleet of vehicles	Diesel vehicles	414	407	-7.3	-1.8%
	Gasoline vehicles	207	168	-39	-19%
	Propane vehicles	8.8	8.8	-0.002	-0.02%
Refrigerants & chemicals	Refrigerants	1,436	1,468	32	2.2%
	Insulating gas	47	47	0.0004	0.0009%
Agriculture	Livestock	520	570	50	9.6%
	Fertilizers	73	73	0.5	0.7%
Scope 1 (direct emissions) - Total		37,958	35,628	-2,331	-6.1%

Scope 2 (energy indirect emissions)					
Purchased energy	Electricity	261	273	12	4.6%
	Steam	952	659	-293	-31%
	Hot water	2,787	2,699	-88	-3.2%
	Chilled water	0.2	0.2	0.005	2.6%
Scope 2 (energy indirect emissions) - Total		4,000	3,630	-369	-9.2%
Scope 3 (indirect emissions)					
Stationary combustion	Natural gas	1,000	815	-184	-18%
	Electricity	14	15	0.4	2.6%
Commuting	Faculty & staff	4,428	4,608	181	4.1%
	Students	2,277	2,316	39	1.7%
Third-party fleet	Macdonald shuttle	176	197	21	12%
Air travel	Directly-financed air travel	8,223	8,087	-136	-1.7%
Sports team travel	Air	153	153	-0.001	-0.0008%
	Bus	78	78	-0.002	-0.003%
	Public transit	1.7	1.7	-0.0004	-0.02%
	Taxi	0.002	0.002	0	0%
Water	Supply	167	155	-12	-7.1%
	Treatment	322	299	-24	-7.4%
Energy losses	Transmission & distribution	20	21	0.6	3.2%
Scope 3 (indirect emissions) - Total		16,861	16,746	-115	-0.7%
Total Emissions		58,819	56,004	-2,815	-4.8%

Non-Inventory Category	Activity	Emissions (tCO_2e) 2015	2017	
Avoided emissions from waste management				
	Solid waste - recycling	-1,006	-840	
	Solid waste - composting	-114	-180	
Avoided emissions from waste management - Total		-1,120	-1,020	
Refrigerants governed by Montreal Protocol				
	Refrigerants (e.g. R22)	242	286	

Table 10 – 2015 vs. 2017 Greenhouse Gas Inventory

As noted earlier in this report, McGill has committed to achieving carbon neutrality by 2040, a commitment that includes the Scope 1, 2 and select Scope 3 emissions shown above. McGill's carbon neutrality target date is re-assessed every three years to take into account potential changes in regulations, available technologies, carbon markets, and climate conditions that could accelerate our timeline. The IPCC's recent "Special report on the impacts of global warming of 1.5°C" will be a critical resource during the next re-assessment period.[5] As noted in the "Vision 2020: Climate & Sustainability Action Plan 2017 – 2020", carbon neutrality initiatives are prioritized in the following order: GHG reductions, carbon sequestration on our own managed lands, and third party carbon offsetting.

C. Benchmarking GHG Emissions

Benchmarking greenhouse gas emissions is an important exercise to allow for comparison between years, against national averages, and amongst peers. This exercise is notoriously challenging given the variety of applied methodologies, GWPs, and Scope 3 sources included, and the difference in energy requirements between research-intensive and non-research focused institutions.

As in the 2015 inventory, we have calculated a number of key performance indicators (KPIs) specific to McGill and compared McGill's performance to other research universities in Québec, Canada and the northeastern United States. Importantly, the below calculations include only building-related Scope 1 and Scope 2 energy and emissions for each institution, in an effort to standardize the comparison; non-building and Scope 3 sources are not included.[6] Emissions and energy are normalized to total student enrolment, gross area, and endowment dollars, three parameters that have a significant impact on GHG emissions at research-intensive institutions. The data period for each institution's performance is noted. Data for this analysis was sourced from the Québec Ministry of Education and Higher Education, the Government of Ontario's Data Catalogue, and reports available from each institution's website.

	McGill University (2016/17)	Rank	Université de Montréal (2016/17)	Université Laval (2016/17)	Université de Sherbrooke (2016/17)	University of British Columbia (2017)*	University of Toronto (2015)	Harvard University (2016)	MIT (2017)	Stanford University (2017)
Region			Quebec			Canada		Northeastern United States		
Emissions										
Emissions/student enrolment tCO_2e/FTE student	1.02	4	0.59	0.69	0.36	1.17	1.50	9.20	15.90	6.19
Emissions/gross area tCO_2e/m^2	0.038	5	0.035	0.032	0.017	0.027	0.085	0.052	0.16	0.066
Emissions/endowment tCO_2e/M$	22	4**	93	212	-	29	56	2.6	10	3.5

5 http://www.ipcc.ch/report/sr15/
6 Scope included in KPI calculations is based on what is reported to the Ministry of Education

Energy										
Energy/student enrolment GJ/FTE student	40	4	24	29	26	50	41	249	59	97
Energy/gross area GJ/m^2	1.75	9	1.51	1.48	1.47	1.13	1.69	1.41	0.58	1.03
Energy/endowment GJ/M$	870	4**	3,802	8,923	-	1,216	1,520	72	38	54

** University of British Columbia - Vancouver Campus*
*** 4th out of 8, since USherbrooke is not included in this metric*

Table 11 – Comparison of Key Institutional KPIs across Select Canadian and American Research Institutions

In addition to our commitment to absolute emission reductions, McGill also aims to improve performance against these benchmarks. The below table highlights our success in improving relative performance from 2015 to 2017.

	2015/2016	2016/2017	% Change
Emissions/student enrolment *tCO_2e/FTE student*	1.12	1.02	-9%
Emissions/gross area *tCO_2e/m^2*	0.045	0.038	-16%
Emissions/endowment *tCO_2e/M$*	24.96	22.18	-11%

Table 12 – 2015 vs. 2017 McGill GHG Emissions KPIs

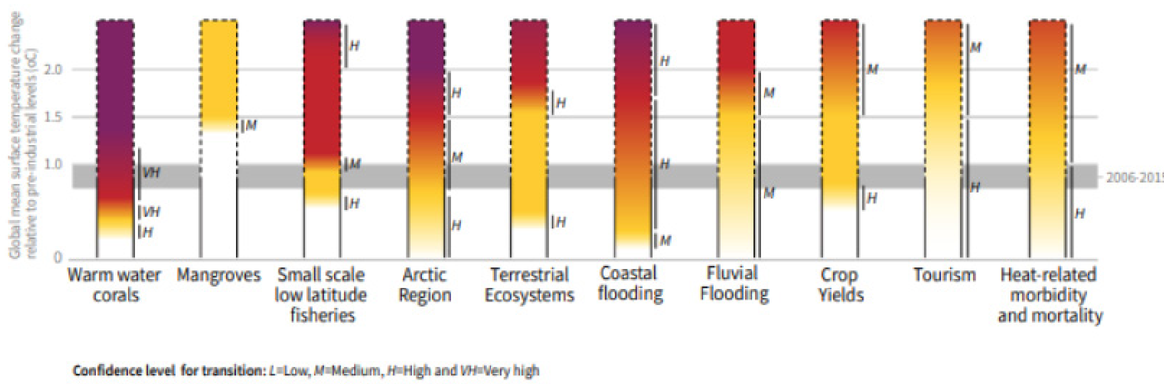
In the 2015 inventory report, we also included benchmarking using data reported to AASHE's STARS program. Per the STARS accreditation program, McGill's Gold rating (and related STARS data) remains valid for three years and will be updated in 2019. We will therefore include an updated STARS benchmarking analysis in either the CY2018 or CY2019 inventory.

D. International and Canadian Context

International Context

The Intergovernmental Panel on Climate Change (IPCC)'s 5th Assessment Report details the emissions reductions needed to achieve each of the potential warming scenarios we face as a global population. Their calculations indicate that global carbon neutrality is required well below 2100 to have a likely chance of limiting temperature increase below 2°C.[7] Importantly, the IPCC's recently released "Special report on the impacts of global warming of 1.5°C" urgently communicates that global action at an unprecedented scale is required immediately – with the next decade being the most critical – if we have a reasonable chance at limiting temperature increase to 1.5°C.

As shown in the below figure,[8] climate science indicates that anticipated risks and impacts under the 2°C scenario are too high for vulnerable populations including least developed countries, small-island developing states, and communities dependent on coastal or agricultural livelihoods, and for ecosystems such as coral reefs and the Arctic. The risks highlighted in the report include those to human health, livelihoods, food security, water supply, human security and economic growth.



Source: Intergovernmental Panel on Climate Change (2018). Special Report: Global Warming of 1.5ºC. https://www.ipcc.ch/sr15/

Figure 6. Impacts and risks for selected natural, managed and human systems

McGill's own target of achieving carbon neutrality by 2040 was selected in part to ensure we align with the minimum targets of the global scientific community. As seen in the below table, global emissions need to be reduced by almost 90% by 2050 (relative to 1990 levels) to have a likely chance of limiting temperature increase below 2°C. The new IPCC special report emphasizes the need to accelerate this timeline, requiring emissions reductions of 45% below 2010 levels by 2030, and achieving net zero emissions by mid-century.

	By 2050	By 2100
Change in CO_2e emissions required to maintain temperature increase below 2°C relative to 1990	avg. ↓87.5%	avg. ↓129%

Table 13 - Average global emission reduction timelines corresponding to the 2-degree scenario

7 Table adapted from Table 3.1 p. 22 of IPCC's AR5:
8 https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf

Canadian Context

Canada ratified the Paris Agreement in 2016 and committed to an economy-wide target of reducing emissions by 30% below 2005 levels in 2030,[9] and 80% below 2005 levels by 2050. Carbon pricing is central to achieving this target. The federal government's embattled Pan-Canadian Framework on Clean Growth and Climate Change from 2016 states that the benchmark carbon price would start at a minimum of $10 per tonne CO_2e in 2018, and rise by $10 each year to $50/tonne CO_2e in 2022.[10] Since Québec already has a legislated cap-and-trade system in place, it is required under this framework to establish a reduction target equal to or greater than Canada's 30% target by 2030 and ensure that annual caps decline to at least 2022. Presently, Québec's target of 37.5% below the 1990 level by 2030 exceeds the federal mandate.[11] Legislation is likely to progress over time, especially within Québec.

At a municipal level, Montreal's targets are to reduce the city's GHG emissions by 30% below 1990 levels by 2020 and by 80% by 2050. The former commitment was made during the 4th Municipal Leaders Summit on Climate Change held in Montreal in December 2005, while the latter came into effect when Montreal ratified the Paris City Hall Declaration[12] in December 2015.

	2009	2020	2050
Montreal's GHG reduction targets, expressed as reductions below 1990 levels	14,090 kt CO_2e	10,509 kt CO_2e (-30%)	3,003 kt CO_2e (-80%)

Table 14 – Montreal's GHG reduction targets

The "Sustainable Montreal 2016 – 2020" plan[13] identifies three sustainable development challenges for the city, and the first is "Low-Carbon Montreal". Specific actions to achieve this goal include reducing automobile dependency and encouraging the use of active and public transit; investing in electric vehicle infrastructure; and building and renovating buildings sustainably. The city plans to work with municipal partners to implement these actions effectively and efficiently.

While renewable energy technologies are an important lever to transform energy systems and reduce emissions, they often have a visual impact – solar collectors, photovoltaic panels and even air-source heat pumps are outdoor installations. This poses a challenge in McGill's downtown context where a large portion of the campus falls into historic or environmental heritage areas with municipal by-laws influencing the feasibility of such installations; the Macdonald campus and the Bellairs Research Institute are under fewer constraints in this regard.

9 http://www4.unfccc.int/ndcregistry/PublishedDocuments/Canada%20First/Canada%20First%20NDC-Revised%20submission%202017-05-11.pdf
10 https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170125-en.pdf
11 http://www.mddelcc.gouv.qc.ca/changementsclimatiques/engagement-quebec-en.asp
12 https://www.uclg.org/sites/default/files/climate_summit_final_declaration.pdf
13 http://ville.montreal.qc.ca/pls/portal/docs/page/d_durable_en/media/documents/plan_de_dd_en_lr.pdf

Peer Context

Around the world, the number of organizations taking action on climate change is steadily increasing. Colleges and universities, uniquely positioned to drive progress towards a sustainable future, are announcing emission reduction targets and committing to carbon neutrality goals.

McGill's peer institutions—Canadian U15 research-intensive universities, AAU public and private colleges, the UK Russell Group, and the Group of Eight in Australia[14]—are also taking these actions. At the time of comprehensive peer analysis in May 2017, thirteen of our peers had publicly announced carbon neutrality commitments, with target dates ranging from 2025 to 2050; unlike McGill, not all peer institutions are including their Scope 3 emissions in their neutrality commitments. It is important to keep in mind that institutional carbon neutrality targets are emerging at an unprecedented rate, so the list of higher education institutions making public commitments will likely evolve quickly.

A comparative analysis of select Canadian and US research universities shows that McGill's absolute emissions are larger than comparable universities in Québec, average compared to other Canadian universities, and much smaller than selected research-oriented US universities.

Scaling Emissions

Climate change is a global issue, requiring ambitious international commitment, action and cooperation. Reduction initiatives are required from all areas – governments, businesses, institutions, cities and regions, and individuals – in order to achieve the dramatic changes required within this timeframe. Commitments made by the federal government of Canada, the provincial government of Québec and the city of Montreal will impact McGill's own reduction efforts, since policies implemented at these levels will affect energy generation, building and renovation codes, vehicle market share and efficiency standards, and investment in renewable energy and public transit. It is therefore interesting to visualize the total emissions at each of these levels, to remind us that our efforts at McGill are contributing to widespread efforts across the province and country.

14 https://www.mcgill.ca/apb/planning/cyclical-unit-reviews/links/peer-institutions

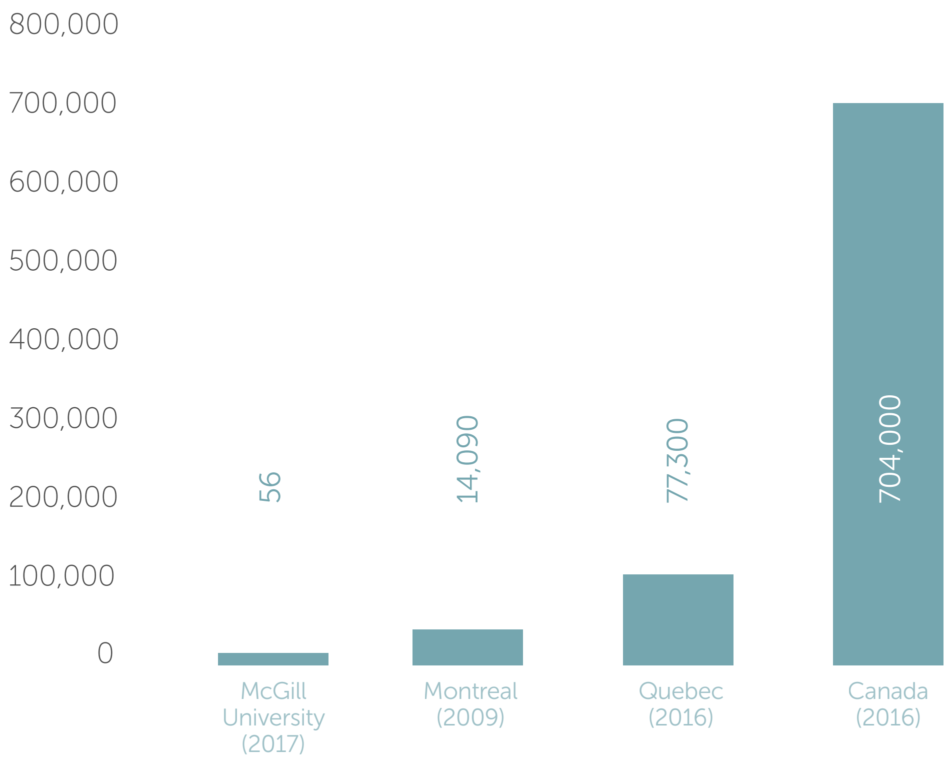


Figure 7 – Comparison of total emissions for different entities (ktCO_2)

Appendix – Detailed Methodology

This section explains the equations used to calculate McGill's GHG emissions in more detail.

1. ON-SITE STATIONARY COMBUSTION

Fuels: natural gas, heating oil, propane, diesel

Activity levels collected from invoices

Equation 1: Calculation of GHG emissions from stationary combustion

$$CO2e = \sum_{i=1}^{n} Fuel_{\,i} \times \left(EF_{CO2,i} \times GWP_{CO2} + EF_{CH4,i} \times GWP_{CH4} + EF_{N2O,i} \times GWP_{N2O}\right)$$

Where:

CO_2e = total greenhouse gas emissions in CO_2 equivalent

Index i refers to each activity

n is the total number of activities

$Fuel_{\,i}$ is the amount of fuel (mass or volume) consumed during the reporting period

$EF_{CO2,i}$ is the CO_2 emission factor for activity i (same thing for CH_4 and N_2O)

GWP_{CO2} is the global warming potential of CO_2 (same thing for CH_4 and N_2O)

2. PURCHASED STEAM (ACCOUNTED FOR UNDER ON-SITE STATIONARY COMBUSTION)

Fuel: steam supplied by a third party (the MUHC).

Activity level: meter readings

Equation 2: Estimating the natural gas equivalent of purchased steam

$$Natural\ gas\ equivalent = \frac{Steam\ consumption}{Production\ eff. \times Distribution\ eff.}$$

Where:

Natural gas equivalent: natural gas consumption at the MUHC powerhouse to deliver steam to McGill

Steam consumption: as read by McGill's steam meter

Production efficiency: assumed to be 29 lb/m^3 of natural gas, i.e. similar to McGill's own powerhouse

Distribution efficiency: assumed to be 90%, i.e. similar to McGill's own steam distribution

The volume thus calculated is then used in Equation 1 to calculate the equivalent CO_2 emissions.

3. ON-SITE MOBILE EQUIPMENT

Fuels: diesel, gasoline

For centrally managed vehicles:

Activity level: from fleet management solution

Equation 3: Calculation of the GHG emissions from mobile combustion

$$CO2e = \sum_{i=1}^{n} Fuel_{\ i} \times \left(EF_{CO2,i} \times GWP_{CO2} + EF_{CH4,i} \times GWP_{CH4} + EF_{N2O,i} \times GWP_{N2O}\right)$$

Where:

CO_2e = total greenhouse gas emissions in CO_2 equivalent

Index i refers to each activity

n is the total number of activities

$Fuel_{\ i}$ is the amount of fuel (volume) consumed during the reporting period

$EF_{CO2,i}$ is the CO_2 emission factor for activity i (same thing for CH_4 and N_2O)

GWP_{CO2} is the global warming potential of CO_2 (same thing for CH4 and N_2O)

For research vehicles:

Activity level: the following assumptions were made:

- Passenger cars: same emissions per vehicle as those calculated for the centrally-managed fleet of vehicles
- Snowmobiles, seadoos, and ATVs: annual distance travelled was estimated
- Tractors: total emissions estimated based on study on agricultural tractors from the US EPA.

4. UNCONTROLLED LEAKS OF REFRIGERANTS

Chemicals: different types of refrigerants

Activity level: calculated using the equations below

Equation 4: Calculation of the amount of refrigerant leaked by mechanical systems

$$Ref_{i,j} = RC_{i,j} \times \left(LR_j + \frac{EOL_j}{EL_j}\right)$$

Where:

$Ref_{i,j}$ is the amount of refrigerant i leaked by system j annually

$RC_{i,j}$ is the charge of refrigerant i of system j, $RC_{i,j} = CC_j \times UC$

CC_j is the total cooling capacity of system j

UC is the unitary charge of refrigerant, assuming 5 lbm of refrigerant per ton of cooling

LR_j is the annual leakage rate of system j, assumed to be 2% for all systems

EOL_j is the end of life refrigerant loss of system j, assumed to be 10%

EL_j is the equipment life of system j, set to 10 years by default

Equation 5: Calculation of GHG emissions from uncontrolled leaks of refrigerants

$$CO2e = \sum_{j=1}^{m} \sum_{i=1}^{n} Ref_{\ i,j} \times GWP_i$$

$CO2e$ is the total greenhouse gas emissions from uncontrolled leaks of refrigerant in CO_2 equivalent

Index i refers to each type of refrigerant; n is the total number of types of refrigerants

Index j refers to each mechanical system with refrigerants; m is the total number of systems

$Ref_{\ i,j}$ is the amount of refrigerant i leaked by system j annually as calculated in **Equation 4**

GWP_i is the global warming potential of refrigerant i

5. UNCONTROLLED LEAKS OF ELECTRICAL INSULATING GAS

Chemical: SF_6

Activity level: calculated using an annual leakage rate of 0.5%

Equation 6: Calculation of GHG emissions from uncontrolled leaks of SF_6

$$Ref_{i,j} = RC_{i,j} \times \left(LR_j + \frac{EOL_j}{EL_j}\right)$$

Where:

CO_2 e is the total greenhouse gas emissions from uncontrolled leaks of SF_6 in CO_2 equivalent

Index j refers to each electrical system which contains SF_6; m is the total number of system

$Mass\ SF6_j$ is the total mass of SF_6 contained in system j

LR is the annual leakage rate of SF_6, assumed to be 0.5%

GWP_{SF6} is the global warming potential of SF6

6. FERTILIZERS

Chemicals: different types of fertilizers

Activity level: annual report from Macdonald Campus (Farm, Horticultural Centre, LODS Research Centre)

Equation 7: Calculations of GHG emissions from fertilizers

$$CO2e = \left(\sum_{i=1}^{n} FC_i \times \%N_i \times EC \times \frac{44}{28}\right) \times GWP_{N2O}$$

Where:
Index i refers to each type of fertilizer used; n is the total number of types of fertilizers used

FC_i **is the is the mass of fertilizer spread**

$\%N_i$ **is the nitrogen content of fertilizer *i***

EC is the emission coefficient and equals 0.0117 tons N_2O-N per ton of N applied

44/28 is the molecular weight ratio of N_2O to N_2O as N (i.e., $N_2O \div N_2O$-N)

GWP_{N2O} **is the global warming potential of N_2O**

7. LIVESTOCK

Activity: different types of farm animals

Activity level: average headcounts estimated for each type of farm animal by the manager of the Macdonald Farm

Emissions come from two main sources: enteric fermentation and manure management.

Equation 8: Calculation of GHG emissions from farm animals

$$CO2e = (CH4_{EF} + CH4_{MM}) \times GWP_{CH4} + N2O_{MM} \times GWP_{N2O}$$

Where

$CO2e$ **is the total greenhouse gas emissions in CO_2 equivalent from farm animals**

$CH4_{EF}$ **is the total CH_4 emissions from enteric fermentation for all animal categories**

$CH4_{MM}$ **is the total CH_4 emissions from manure management for all animal categories**

$N2O_{MM}$ **is the total N_2O emissions from manure management for animal categories**

GWP_{CH4} **and** GWP_{N2O} **are the global warming potentials of CH_4 and N_2O respectively**

Equation 9: Calculation of CH_4 emissions from enteric fermentation

$$CH4_{EF} = \sum_i N_i \times EF_{EF_i}$$

Where:

$CH4_{EF}$ is the total CH_4 emissions from enteric fermentation for all animal categories

Index *i* refers to each animal category

N_i is the total population of each animal category

EF_{EF_i} is the CH_4 emission factor from enteric fermentation for each animal category

Equation 10: Calculation of CH_4 emissions from manure managementtion

$$CH4_{MM} = \sum_i N_i \times EF_{MM_i}$$

$CH4_{MM}$ is the total CH_4 emissions from manure management for all animal categories

Index *i* refers to each animal category

N_i is the total population of each animal category

EF_{MM_i} is the CH_4 emission factor from manure management for each animal category

Equation 11: Calculation of N_2O emissions from manure management

$$N2O_{MM} = \sum_j \sum_i N_i \times N_j \times N_{EX,i} \times EF_j \times \frac{44}{28}$$

$N2O_{MM}$ is the total N_2O emissions from manure management for all animal categories

Index *j* refers to each type of waste management system

Index *i* refers to each animal category

N_i is the total population of each animal category

N_j is the percentage of nitrogen handled by each animal waste management system

$N_{EX,i}$ is the nitrogen excretion rate for each animal category

EF_j is the N_2O emission factor from manure management for each animal waste management system

8. PURCHASED ELECTRICITY

Fuel: electricity generated by Hydro Québec for facilities in Québec and BLPC for facilities in Barbados

Activity level: energy consumption from invoices

Equation 12: Calculation of greenhouse gas emissions from electricity consumption

$$CO2e = \sum_{i=1}^{n} Fuel_{\,i} \times EF_i$$

CO_2e is the total greenhouse gas emissions from electricity consumption in CO_2 equivalent

Index i refers to each supplier

$Fuel_{\,i}$ is the total electricity purchased from supplier i

EF_i is the emission factor for each utility company in g CO_2 equivalent per kWh consumed

9. DIRECTLY-FINANCED AIR TRAVEL

Activity: air travels financed by McGill (faculty, students, and staff)

Activity level: annual compilation of reimbursement claims submitted by all travellers

Equation 13: Calculation of greenhouse gas emissions from directly-financed air travel

$$CO2e = \sum_{i=1}^{n} Distance_{\,i} \times \left(EF_{CO2,i} \times GWP_{CO2} + EF_{CH4,i} \times GWP_{CH4} + EF_{N2O,i} \times GWP_{N2O}\right)$$

Where:

CO_2e = total greenhouse gas emissions in CO_2 equivalent

Index i refers to each journey

n is the total number of journey

$Distance_i$ is the total distance travelled in passenger-km for each journey

$EF_{CO2,i}$ is the CO_2 emission factor for journey i (same thing for CH_4 and N_2O)

$EF_{CO2,i}$ has different values depending on the length of the journey leg (short haul <300 miles, medium haul ≥300 miles and <2,300 miles, and long haul ≥2,300 miles) (same applies to CH_4 and N_2O)

GWP_{CO2} is the global warming potential of CO_2 (same thing for CH_4 and N_2O)

10. COMMUTING

Activity: commuting of McGill students, faculty, and staff to and from the two main campuses

Method: emissions calculated in survey from McGill's School of Urban Planning "Transportation Research at McGill" (TRAM) team and re-adjusted to enrollment and staff headcount

11. SPORT TEAMS TRAVEL

Activity: sport teams travelling to sport meets

Activity level: total distance travelled computed by student intern

Equation 14: Calculation of the greenhouse gas emissions from sport teams travels

$$CO2e = \sum_{i=1}^{n} Distance_{\ i} \times \left(EF_{CO2,i} \times GWP_{CO2} + EF_{CH4,i} \times GWP_{CH4} + EF_{N2O,i} \times GWP_{N2O} \right)$$

Where:

CO2e = total greenhouse gas emissions in CO_2 equivalent

Index i refers to each journey

n is the total number of journey

$Distance_i$ is the total distance travelled in passenger-km for each journey

$EF_{CO2,i}$ is the CO_2 emission factor for journey i (same thing for CH_4 and N_2O)

$EF_{CO2,i}$ has different values depending on transportation mode and on the length of the journey leg for air travel (ref. Equation 12 same applies to CH_4 and N_2O)

GWP_{CO2} is the global warming potential of CO_2 (same thing for CH_4 and N_2O)

12. WATER SUPPLY

Activity: greenhouse gas emissions related to the treatment and distribution of fresh water by the City of Montréal and the City of Sainte-Anne-de-Bellevue

Activity level: total consumption estimated in water audits of the Downtown and Macdonald campuses

Equation 15: Calculation of greenhouse gas emissions from water supply

$$CO2e = \sum_{i=1}^{n} Water\ Consumption_i \times EF_i$$

Where:

$CO2e$ is the total greenhouse gas emissions from water consumption in CO_2 equivalent

Index *i* refers to each campus

$Water\ Consumption_i$ is the total water consumed on campus i in m^3

EF_i is the emission factor applicable to each campus in g CO_2 equivalent per m^3 consumed. These factors were computed by McGill students in an ENV-401 research project.

13. WASTEWATER TREATMENT

Activity: greenhouse gas emissions related to the collection and treatment of wastewater at Montréal's wastewater treatment plant

Activity level: total effluents estimated by ENV-401 student research project

Equation 16: Calculation of greenhouse gas emissions from water supply

$$CO2e = \sum_{i=1}^{n} Wastewater_i \times EF_i$$

Where:

CO_2 e is the total greenhouse gas emissions from water consumption in CO_2 equivalent

Index i refers to each campus

$Wastewater_i$ is the total wastewater from campus i in m^3

EF_i is the emission factor applicable to each campus in g CO_2 equivalent per m^3 consumed. These factors were computed by McGill students

14. POWER TRANSMISSION & DISTRIBUTION LOSSES

Activity: electricity transmission and distribution losses

Activity level: calculated from utility invoices (Hydro Québec and BLPC)

Equation 17: Calculation of greenhouse gas emissions from power transmission and distribution losses

$$CO2e = \sum_{i=1}^{n} Fuel_{\,i} \times TDLF_i \times EF_i$$

Where:

CO_2 e is the total greenhouse gas emissions from electricity transmission and distribution losses in CO_2 equivalent

Index i refers to each supplier

$Fuel_{\,i}$ is the total electricity purchased from supplier i

$TDLF_i$ is the average transmission and distribution loss factor for supplier i

EF_i is the emission factor for each utility company in g CO_2 equivalent per kWh consumec

15. SOLID WASTE

Activity: reduction in greenhouse gas emissions from the management of waste generated on the Downtown and Macdonald campuses

Activity level: monthly reports from contracted landfilled waste and recycling suppliers (downtown and Macdonald campuses) and compost supplier (downtown campus) + estimate for compost at Macdonald Campus

The difference between the baseline (100% of waste to landfill) and actual (a mix of recycling, composting, and landfilling) disposal streams was calculated using the US EPA's WARM model. The different categories considered are yard trimmings, mixed paper, mixed recyclables, food waste, and mixed municipal solid waste (MSW).