Emission Inventory Report:

University of Manitoba Climate Action Plan

IISD
International Institute for Sustainable Development

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EXECUTIVE SUMMARY

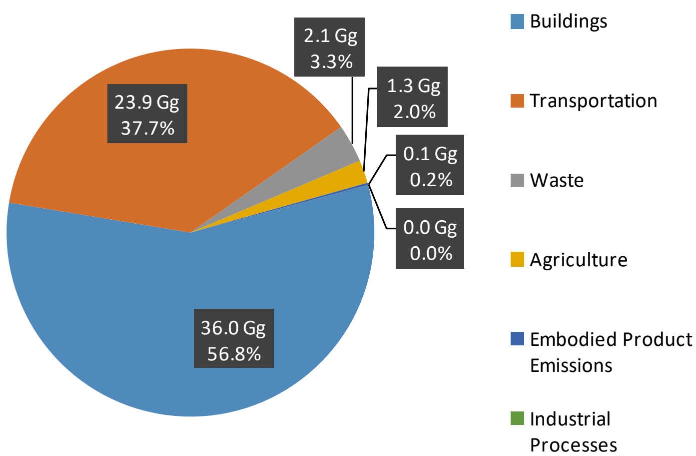
This report presents a greenhouse gas (GHG) inventory and baseline projection for the University of Manitoba that can be used for reporting, planning and measuring progress towards GHG emission reduction targets. Methods used for accounting and reporting of GHG emissions are consistent with best practices and follow accepted principles of inventory preparation.

The inventory includes all direct emission sources from owned or controlled processes (Scope 1 emissions) and indirect emissions associated with the generation of purchased energy (Scope 2 emissions). In addition, some Scope 3 emissions (indirect emissions that occur in the value chain upstream and downstream of the university) have also been included where the university has at least partial control and the ability to mitigate these emissions.

An expansive network of services on several campuses at the University of Manitoba contribute to GHG emissions. All of these emissions can be subdivided into six major emission source categories: buildings, transport, agriculture, industrial processes, waste and embodied product emissions. Historic activity data and associated emission factors were collected for the identified emission sources and include all relevant GHGs: carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O) and hydrofluorocarbons (HFCs). Baseline projections were estimated using different drivers of emissions, including expected student and faculty population growth, building area growth and expected changes in energy efficiency due to equipment replacement and new technologies.

Total GHG emissions were estimated at 59,790 tonnes of carbon dioxide equivalent (tCO_2e) in the 2015/16 fiscal year (FY). This is equivalent to 59.79 gigagrams or kilotonnes of CO_2e. The sectoral breakout is shown in Figure ES1.

Figure ES1. Total GHG emissions by emission source category ($GgCO_2e$)



Note: Industrial process and embodied product emissions are so small they cannot be seen in the figure.

Building emissions comprise more than half of overall emissions, while building and transport emissions combined are equal to 94 per cent of total emissions. Waste and agriculture emission categories contribute a smaller amount of emissions, between 2 and 3 per cent. Embodied product and industrial process emission categories contribute emissions that are practically neglibile overall.

In terms of both scope and emission source, there are five emission sources that make up more than 95 per cent of all emissions, as illustrated in Table ES1.

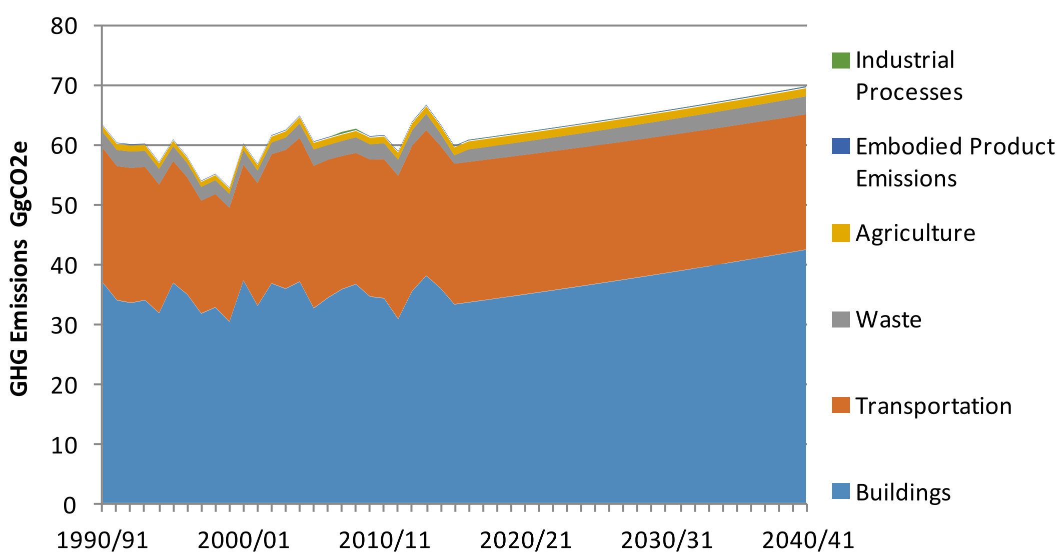
Table ES1. Comparison of most important emission sources to overall contribution

Category	Sub-Category / Emission Source	Scope	Rank	Emissions (tCO_2e)	% of Total
Buildings	Heating	Scope 1	1	25,444	42.6%
Transportation	Commuting	Scope 3	2	12,915	21.6%
Transportation	Business	Scope 3	3	9,835	16.4%
Buildings	Heating	Scope 2	4	7,341	12.3%
Waste	Solid Waste Disposal	Scope 3	5	1,418	2.4%

Agricultural emissions are also significant, with manure management and enteric ferementation contributing about 2.3 per cent of the remaining emissions in FY 2015/16.

Historic and baseline emissions projected out to FY 2040/41 are shown in Figure ES2.

Figure ES2. Projected GHG emissions by emission source category ($GgCO_2e$)



Note: Industrial process and embodied product emissions are so small they can't be seen in the figure.

While historical emissions have been relatively stable, despite significant growth on campus and more students and University staff, baseline projections show overall emissions increasing by approximately 0.7 per cent per year on an annual basis or by 18 per cent in absolute terms over the next 25 years. However, overall emission intensity expressed as the total GHG emissions divided by the total expected student and staff population in $kgCO_2e$/person is expected to decline in the future. Historical average emission intensity has fallen from a peak of 2,075 $kgCO_2e$/person in FY 1995/96 to a current level of 1,537 $kgCO_2e$/person in FY 2015/16. This represents a decrease of 25 per cent in emission intensity. In the future this trend is expected to continue and the emission intensity in FY 2040/41 is projected to fall to 1,239 tCO_2e/person, a further decrease of 19 per cent from FY 2015/16.

Contents

INTRODUCTION

This report by the IISD team presents an emission inventory and baseline projection for the University of Manitoba. The report covers the historical period between fiscal years (FY) 1990/91 to the most recent year with available data (FY 2015/16) and then presents a baseline emissions projection until 2040. Methods used to generate the emission inventory are consistent with best practice for institutional emission inventory development and align with the principles for accounting and reporting of greenhouse gas (GHG) emissions by corporate entities including A *Corporate Accounting and Reporting Standard,* published by the World Business Council for Sustainable Development.[1]

The inventory is prepared in accordance with the principles of: relevance, completeness, consistency, transparency and accuracy, and includes both direct and indirect emissions arising from the activities of the university. Some considerations were made in regards to whether different types of emission sources should be included or excluded. The inventory prioritizes direct emission sources and focuses on emission sources where the university has at least partial control over the emissions, either through procurement strategies, contracting requirements or planning, and where there are management options available to the university to mitigate or reduce these emissions.

General methods used to develop the emission inventory and baseline projection are presented in the approach section that follows. Main emission source categories by sector are then reviewed, discussing specific methodologies, the major data sources and gaps as well as the results. Finally, a conclusion section summarizes the emission trends and learnings from conducting the inventory work. An Annex provides futher details on the emission inventory and baseline projection tool developed for the project.

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[1] World Resources Institute and World Business Council for Sustainable Development (2015). *A corporate accounting and reporting standard*. Revised Edition. The Greenhouse Gas Protocol.

APPROACH

The objective of the report is to develop and present a complete and robust GHG inventory and baseline projection that can be used for reporting, planning and measuring progress towards GHG emission reduction targets. This may include potential reporting requirements under new Manitoba regulations that have been discussed, but, as of yet, not developed. Without specific Manitoba reporting regulations, the project work is based on a best estimate of what these reporting requirements may be, on reporting regulations in other jurisdictions, as well as, generally accepted accounting and reporting requirements.

Methods used for accounting and reporting of GHG emissions are consistent with best practice for corporate reporting of emissions and are based on a number of different documents including the *A Corporate Accounting and Reporting Standard* published by the World Business Council for Sustainable Development.[2] These guidelines focus on the same principles that are used to prepare national inventories: relevance, completeness, consistency, transparency and accuracy.

General steps in the approach are briefly described below, while more detailed methodological steps for each major category of emissions are outlined in the subsequent subsections.

The first step in the development of the GHG inventory is to identify the boundary and scope of emissions to include in the inventory. Emissions can be categorized as: Scope 1 emissions, which are direct emissions from owned or controlled processes; Scope 2 emissions, which are indirect emissions associated with the generation of purchased energy; or Scope 3 emissions, which are indirect emissions that occur in the value chain upstream and downstream of the university (for example, embodied emissions in the products that are purchased by the university). Definitions for these emission scopes are well accepted for GHG inventories and align with the World Resource Institute's Greenhouse Gas Protocol for corporations.[3]

The second step is to determine the methodologies that will be used to estimate historic emissions from existing activity data. These methodologies are consistent with best practice for corporate reporting[4] as well as with Canada's National Inventory Report.

The third step is to determine the methodologies that will be used to estimate baseline emission projections from FY 2016/2017 to 2040/41. These projections will give a sense of trends and what emissions will look like in the future if no additional policies or efforts to reduce emissions are implemented from today.

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[2] World Resource Insittute & World Business Council for Sustianable Development. (2015). *A corporate accounting and reporting standard*. (rev. ed.). Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/corporate-standard

[3] Ibid.

[4] Ibid.

The fourth step is to identify the process for data collection, describing how important activity data, projection information and emission factors were collected.

The last step is to provide an overview of the approach in preparing the emission inventory and baseline projection tool that was developed to calculate, project and present GHG emissions for the University of Manitoba.

Boundary and Scope of Emission Inventory

The University of Manitoba operates an expansive network of services on several campuses and manages a large number of buildings and assets. GHG protocols[5] identify that the university should account for 100 per cent of the GHG emissions from operations over which it has operational control. It is not required to account for GHG emissions from operations where it owns an interest but does not have control, for example, the lease of building space to other tenants.

The second aspect of boundaries is deciding on wether to include only Scope 1 and Scope 2 emissions, or whether to include Scope 3 emissions. Early in the project, a discussion on setting these boundaries was held with the University of Manitoba to reach an agreed approach. This inventory makes all reasonable attempts to identify and quantify all direct emissions associated with energy (Scope 1), as well as indirect emissions associated with purchased electricity or steam (Scope 2). Because of the importance of agriculture activities to the University of Manitoba, direct emissions associated with agriculture activities are also of concern. However, it should be noted that although Agriculture and Land-Use, Land-Use Change and Forestry (LULUCF) are Scope 1 emissions (direct emissions that are argueably under the control of the university), these types of emissions are almost never included in corporate or institutional inventories. In addition these direct emission sources are also very unlikely to be part of any reporting or regulatory requirements because of the difficulty and uncertainty in accounting for the emissions and the ownership of the emissions.

However, the inventory includes some agricultural emission sources as well as some important Scope 3 emissions where the following criteria are met:

1. There is recognition that the university has at least partial control over the emissions, either through procurement strategies, contracting requirements or planning, and that there are management options available that the University can implement to mitigate or reduce these emissions.

[5] These protocols include: (i) World Resource Insittute & World Business Council for Sustianable Development. (2015).(Ibid.); (ii) International Standard ISO 14064-1: 2006 Part One: *Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals,* which was available from the University of Manitoba's Donald W. Craik Engineering Library Standards Collection (TA 404 C3 C3 no.CAN/CSA-ISO 14064-1:06); and (iii) The Climate Registry (2014). *General Reporting Protocol* (TCR: GRP). Retrieved from http://www.theclimateregistry.org/wp-content/uploads/2014/11/TCR_GRP_Version_2.0-1.pdf

2. There is some demonstration in the literature that other organizations and entities have included these emission sources and existing methodologies are available to estimate them with a reasonable level of certainty.
3. The emissions are material to the overall emission inventory (above a threshold of 0.5 per cent relative to total emissions).
4. It is reasonable to expect the university to collect the required activity data in order to estimate emissions and to continue collecting the data on an ongoing basis for inclusion in future inventory work.

All emissions sources included in the inventory are identified in Table 1. There were some instances where direct emission sources were identified but understood to be very small relative to other emission sources (less than 0.1 per cent). In these cases, it is recommended to exclude these direct emission sources from the inventory.

Table 1. Scope of emission inventory for the University of Manitoba

Scope	Category	Sub-Category	Emission Source
Scope 1	Building Energy	Heating	Central Power Plant, Boilers, Heaters
	Agriculture	Livestock	Enteric Fermentation, Manure Management
	Transportation	On-Road Vehicles	University Fleet Vehicles
	Industrial Processes	Refrigerants	HFC Leaks
		Nitrous Oxide	Medical Uses of Nitrous Oxide
Scope 2	Building Energy	Purchased Electricity	Utility Power Plants
		Purchased Pressured Steam	Supplier Boiler
		Purchased Chilled Water	Supplier Chillers, Cooling
Scope 3	Transportation	Commuting	Personal Vehicle, Transit
		Shuttle Services	Buses
		Business-Related Travel Including Offsite Purchases	Air, Bus, Taxi, Train, On Road Passenger Vehicle
	Waste	Solid Waste Management	Landfill
	Embodied Product Emissions	Paper	Paper Purchased by University

Emission Inventory Methodology

GHG accounting and reporting is guided by five principles. The application of these principles is fundamental to ensuring that the information collected is a true and fair account of the context in which the inventory was completed.

- **Relevance:** To ensure that the GHG inventory approach appropriately reflects the GHG emissions of the company/organization and serves the decision-making needs of users.

- **Completeness:** To account for and report on all relevant GHG emission sources, removals and activities within the chosen inventory boundary. If there are excluded areas within the chosen boundary, those exclusions need to be disclosed and the reasons as to why they needed to be excluded need to be justified.

- **Consistency:** Methodologies should be consistent to allow for meaningful comparisons of emissions over time.

- **Transparency:** All relevant assumptions are disclosed and appropriate references to the accounting and calculation methodologies and data sources are used.

- **Accuracy:** All sufficient and appropriate GHG-related information needs to be accounted for in the inventory. One can reduce bias and uncertainty by ensuring that the quantifications are "systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable."[6]

All GHG emissions estimated in this report use methodologies that follow these principles. In the simplest form, emissions are estimated by multiplying some type of activity data by an appropriate emission factor. This method is consistent with inventory guidelines including emission inventory guidelines such as the *2006 IPCC Guidelines*[7] and estimation methodologies used to estimate emissions for Canada's *National Inventory Report*.[8] The general methodology is expressed in Equation 1:

EQUATION 1

$$Emissions_{GHG} = \sum Activity\ Data\ \times Emission\ Factor_{GHG}$$

$Emissions_{GHG}$ = Emissions of a given GHG (kg GHG)

[6] Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[7] Ibid.
[8] Environment Canada. (2016). *National Inventory Report 1990–2014: Greenhouse gas sources and sinks in Canada*. Canada's Submission to the United Nations Framework Convention on Climate Change. Retrieved from https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=662F9C56-1

Activity Data = Unit of activity such as TJ of fuel consumption, tonnes of industrial production or waste generation that may be further disaggregated by technology, end-use or fuel type (unit of activity)

Emission $Factor_{GHG}$ = Default emission factor of a given GHG that corresponds to the unit of activity (kg GHG gas/unit of activity)

All relevant GHGs that are estimated for national inventories are included in the inventory. These include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydroflurocarbons (HFCs). Other GHGs included in national inventories, such as pefluorocarbons (PFCs) and sulphur hexafluoride (SF_6), do not arise from activities within the operational boundary of the University of Manitoba.

GHG emissions are expressed as CO_2e (carbon dioxide equivalent). The carbon dioxide equivalent is calculated using the 100-year global warming potentials for specific gases that are identified for use in Canada's latest *National Inventory Report*.[9] Table 2 summarizes the global warming potentials (GWP) that are used in the inventory. GWP is a relative measure of the warming effect that the emission of a radiative gas (i.e., a GHG) might have on the surface atmosphere and was developed to allow a comparison fo the ability of each GHG to trap heat in the atmosphere relative to carbon dioxide. As such the 100-year GWP defined in the table below is the 100-year change in radiative forcing due to the instantaneous release of 1 tonne of the substance expressed relative to the radiative forcing from the release of 1 tonne of CO_2. The GWP is used to determine the carbon dioxide equivalent (CO_2e) value, calculated by multiplying the amount of the gas by its associated GWP.

Table 2. 100-year global warming potentials used in inventory

GHG	100 year GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
HFC 134	1,100
HFC 134A	1,430
HFC 404A (44% HFC-125, 4% HFC134a, 52% HFC143a)	3,922
HFC 410a (50%HFC-32, 50%HFC-125)	2,088

Source: Environment Canada. (2016). *National Inventory Report 1990–2014: Greenhouse gas sources and sinks in Canada*. Canada's Submission to the United Nations Framework Convention on Climate Change.

[9] Ibid.

Baseline Emission Projection Methodology

Projections are based on the expected change over time in the activity or in the emission factor. Detailed forecasts of changes in activity (e.g., actual fuel useage, population of animals) are difficult to develop as there are a lot of variables that can affect the forecast. For example for building energy use, changes in technology, changes in efficiency, potential changes in fuel, changes in existing demand loads as a result of improvements in building envelope, and changes in use patterns as well as new additions of buildings all need to be considered. Instead, the inventory develops a simplified approach that relates emissions to specific drivers such as population, projected building area and changes in average energy demand. In some cases, it is also possible to consider historic trends as an indicator of future trends in demand.

Changes in energy related emissions include an annual estimate of autonomous energy efficiency improvement,[10] for example, an improvement in overall energy efficiency of 0.5 per cent per year.

Table 3 identifies some of the most important emission projection drivers adopted in the inventory.

Table 3. Annual changes associated with emission projection drivers

Emission Projection Driver	Basis for Value	Annual Change (2016 to 2040)
Student and Faculty Population (including administration staff)	Historic Population trend of last 10 years	+1.5%
Heat and Cooling Autonomous Energy Efficiency Change[1]	Typical baseline value for different energy end-uses	-0.5%
Vehicle Autonomous Energy Efficiency Change[1]	Typical baseline value for different energy end-uses	-1.6%
Electricity Autonomous Energy Efficiency Change[1]	Typical baseline value for different electricity end-uses	-0.8%
Campus Building Area	Historic change in square footage over last 10 years	+1.2%

Note: 1 Autonomous Energy Efficiency is typically expressed as an improvement but is expressed here as a change so that a negative annual change indicates declining emissions for the same level of service.

[10] Best practice in developing baseline projections requires that we account for significant drivers of change in the baseline and the autonomous energy efficiency improvement (AEEI) is a standard way for models to account for these technological and efficiency changes. AEEI is expressed as the annual rate at which equipment or other type of energy end-use uses less energy than the equipment installed in the previous year. Changes in overall efficiency are driven by the replacement rate, modifications, as well as new technologies.

Data Collection

The starting point for inventory data collection was a previous inventory developed for the University for FY 2013/14.[11] However, this inventory focused on a single year and did not include, or misrepresented, a number of important emission sources that are included in this inventory report. Requirements for additional data collection were identified and undertaken through bilateral engagement with various university departments and contacts.

A centralized and accessible dropbox database was set up so that key contacts could place all inventory data in one location and the team could have direct access. Wherever possible, original activity data from logs, receipts and accounting were collected. This reduced the possibility of mistakes or misunderstandings occurring and provides a clear tracking system for future inventory work. Data gaps were identified early in the process and highlighted in reports so that they could be discussed with key contacts at the university with the best knowledge of the activity. The dropbox inventory data folder is organized into the following subfolders that align with the emission source categories:

- Agriculture
- Embodied Product Emissions – Paper
- Buildings – Energy
- Industrial Processes
- Transportation
- Waste

References to the activity data and emission factors used to develop emission estimates are identified in the accompanying baseline emission inventory and are also clearly outlined in the projection tool described below. This enables future inventory teams to easily identify the methodologies, activity datasets and emission factors that were employed.

Emission Inventory and Baseline Projection Tool

An emission inventory and baseline projection tool was developed for this project to track activity data and emission factors and calculate an emissions baseline scenario for the FYs between 1990/91 and 2040/41. The tool is developed in Microsoft Excel, making it accessible for basic users without any software requirements or additional costs. The tool is a simple accounting emission projection model that considers where the university is headed without additional actions on climate change. The baseline can be used to consider the impact of potential mitigation actions and to measure the progress of the university towards meeting future targets.

[11] University of Manitoba. (2015). *Emissions inventory for the University of Manitoba FY 2013/14. Emission Inventory Guid*e. Draft August 2015. Office of Sustainability.

The first step of tool development was to organize the tool into clear modules that relate to different emission categories and scope. A total of eight worksheets are used. The relationship between worksheets and emission sources is identified in Table 4.

Table 4. Baseline emission projection tool hiearchy of model worksheets and emission sources

Worksheet / Category	Scope	Emission Source		
		Level 1	Level 2	Level 3
Building - Direct Energy All direct combustion fuel use associated with buildings	***Scope 1***	***Fuel Type*** Natural Gas, Fuel Oil	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***End-Use*** All end-use is heating but other types of end-uses could be included
Building - Electricity Indirect electricity consumption	***Scope 2***	***Electricity Source*** Manitoba Hydro	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***End-Use*** No data on end-uses so this sub-categorization is not used
Building - Indirect Energy Indirect steam and chilled water consumption	***Scope 2***	***Indirect Source*** Steam, Chilled Water	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***End-Use*** No data on end-uses so this sub-categorization is not used
Transportation Direct and Indirect transport fuel consumption consumption	***Scope 1*** (fleet operations) ***Scope 3*** (commuting, shuttle service, business travel)	***Fuel*** Gasoline, Diesel, Jet Fuel	***Sub-Sector*** Fleet Operations, Commuting, Shuttle Service, Business Travel	***End-Use*** For Commutting end-use divided into Single Occupancy Vehicle, Transit and Carpool. For Business Travel divided between Air and Vehicle Travel
Agriculture Emissions arising from agricultural activities	***Scope 1***	***Emission Source*** Enteric Fermentation, Manure Management	***Activity Data*** Type of Livestock	
Industrial Processes Emissions arising from non-combustion activities on campus	***Scope 1***	***Emission Source*** Nitrous Oxide, Ozone Depleting Substances (HFCs)	***Activity Data*** Nitrous Oxide Bulk Purchase, HFCs	
Waste Emissions arising from waste management	***Scope 3***	***Emission Source*** Solid Waste Disposal	***Activity Data*** Solid Waste Generated	
Embodied Product Emissions Emissions arising from the production of products purchased by the University of Manitoba	***Scope 3***	***Emission Source*** Embodied Paper Products	***Activity Data*** Virgin Paper, Predominantly Recycled Paper, Paperboard	

The structure of each sector worksheet is identical and is designed to be easily updateable as new activity data is collected in future years. Each worksheet provides tables to enter historic data and emission factors for each of the pertinent emission sources. Worksheet Table 1 relates to historic activity data. Table 2 relates to emission factors. In Table 3, emissions are calculated and Table 4 allows the user to generate a summary of calculated emissions and trend figures.

Additional worksheets are provided to define key inventory parameters (e.g., global warming potentials, projection drivers) and a summary and graphic visualization tools. Additional details and instructions for use of the inventory tool are provided in Annex 1.

BUILDINGS

Methodology

The Buildings category includes direct emissions associated with heating buildings, as well as indirect emissions associated with purchased electricity, steam and chilled water. Purchased electricity is used for many different building end-uses (e.g., plug-load, cooling, heating, lighting, refrigeration). Purchased steam is used exclusively for heating and purchased chilled water is used exclusively for cooling. Table 5 summarizes the Building emission sources included.

Table 5. Buildings emission sources

Scope	Building End-Use	Fuel / Energy	Emission Sources
Scope 1	Heating	Natural Gas	Power House, boilers, heaters
		Fuel Oil	Power House, boilers, heaters
Scope 2	All Electric End-Uses	Purchased Electricity	Manitoba Hydro Utility power plants
	Heating	Purchased Pressured Steam	Health Science Centre boiler
	Cooling	Purchased Chilled Water	Health Science Centre chiller

Historic emissions are calculated by multipling the quantity of fuel or energy consumed during the entire FY with appropriate emissions factors. Projections of future emissions are based on anticipated growth in total student and staff population, as well as expected changes in end-use efficiency. Despite the fact that electricity consumed by the University of Manitoba is almost exclusively from hydropower and non-emitting energy, there is a small amount of emissions still associated with electricity. This can include the use of coal or natural gas in times of emergency, or a need to import power in times of shortage.

Activity Data and Assumptions

Table 6. Activity data and assumptions used for the building sector

Type of Activity Data	Fuel /Energy	Source of Data	Notes and Assumptions
Historic Activity Data	Natural gas (cubic meters), fuel oil (litres), purchased electricity (kwh), purchased steam (lbm), purchased chilled water (tonh).	Summary energy-use spreadsheets provided by by Mike Ferley from Physical Plant - Engineering Services • Utility Square Footage Costs • External Customer Billings • Actual Emissions with Energy Mix Graph (1990 to 2005/06) • Fuel spending reports from contracts between April 2013 to November 2016	Energy use of external customers that are included in University of Manitoba billings were backed out of the data so that emissions not under the control of the University from leased space are not included. Annual consumption is divided by some building groups for years after FY 2011/12 so that performance at the building level can be considered.
Projection Data	Student and faculty population	The rate of increased student and faculty population is based on the historic trends over the last nine years and is +1.5 per cent per year. The data was gathered from the Office of Institutional Analysis Enrolment and Academic and Support Staff Reports. http://umanitoba.ca/admin/oia/	Historic growth may not be representative of future growth. Longer-term growth over the last 18 years has been closer to 2.0 per cent.
	Natural gas (cubic meters), fuel oil (litres), purchased steam (lbm), purchased chilled water (tonh)	The rate of heating and cooling annual autonomous energy-efficiency change was estimated to be -0.5 per cent per year until 2040.	The projected baseline improvement rate in energy efficiency for cooling and heating is small in large part because of the considerable work the University of Manitoba has already done over the last two decades to improve the performance of the Power House and campus distribution system. In addition, the purchased steam and chilled water are not under the control of the university.
	Purchased electricity (kwh)	The rate of electricity annual autonomous energy-efficiency change was estimated to be -0.8 per cent per year until 2040.	The projected baseline improvement rate in energy efficiency for electricity end-uses is driven by new technologies such as efficient lighting and appliances. The potential improved efficiency of new technologies is much higher; however, their adoption in the baseline is not assured and there is a counter trend of increased demand from more appliances that is considered in the applied improvement rate.
Emission Factors	Natural gas (cubic meters), fuel oil (litres)	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part II. Annex 6.	Manitob-specific emission factor used for natural gas. Includes CO_2, N_2O and CH_4 emission factors.
	Purchased electricity (kwh)	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part III. Annex 13.	Manitoba consumption intensity (net of transmission and distribution losses) is used. Emission rates vary every year depending on dispatch and generation by fuel type.
	Purchased steam (lbm)	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part II. Annex 6.	Emission rate assumption is 99 per cent natural gas and 1 per cent fuel oil. Overall boiler conversion efficiency associated with Health Science Centre is assumed to be 76 per cent.
	Purchased chilled water (tonh)	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part III. Annex 13.	Chilled water demand in (tonh) is converted to (kWh) demand using energy conversion factor of 3.6, and an assumed average energy conversion chiller efficiency of 80 per cent.

Results

Building emissions related to energy consumption for heating, cooling and electricity end-uses comprise the largest emission category of the inventory (Buildings, Transportation, Agriculture, Industrial Processes, Embodied Product Emissions).

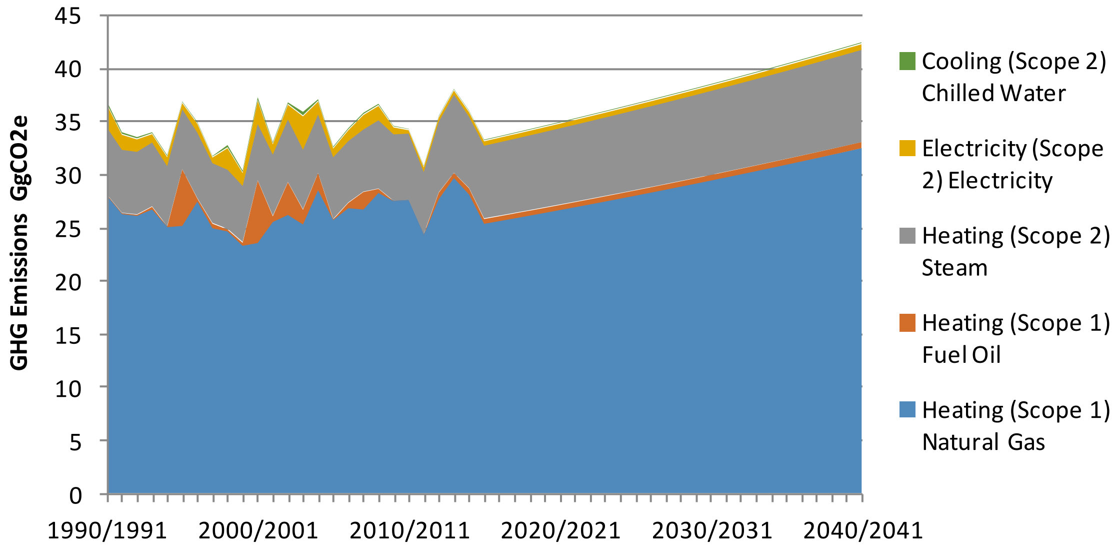
Building-related emissions are summarized in Table 7 for both direct (Scope 1) and indirect (Scope 2) emission sources. Natural gas heating emissions account for more than three quarters of building emissions and are also divided by campus in the table to indicate the relative useage of this important emission source. The table presents historic annual emissions starting in FY 1990/91 at five-year intervals until the most recent FY of the inventory, FY 2015/16. Projections at five-year intervals are also presented until FY 2040/41. These emissions and their annual variation are also illustrated in Figure 1.

Table 7. Building GHG emissions by emission source (tCO2e)

Emission Source			Historic Emissions						Projections				
			1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Fort Garry Campus	Heating (Scope 1)	Natural Gas	NA	NA	NA	NA	NA	25,408	26,937	28,007	29,404	30,870	32,410
Bannatyne Campus	Heating (Scope 1)	Natural Gas	NA	NA	NA	NA	NA	36	37	39	41	43	46
TOTAL Heating (Scope 1)		**Natural Gas**	**28,068**	**25,246**	**23,664**	**25,779**	**27,605**	**25,444**	**26,713**	**28,046**	**29,445**	**30,914**	**32,456**
Fort Garry Campus	Heating (Scope 1)	Fuel Oil	68	5,245	5,792	62	6	446	468	491	516	542	569
Fort Garry Campus	Electricity (Scope 2)	Electricity	NA	NA	NA	NA	NA	345	362	380	399	419	440
Bannatyne Campus	Electricity (Scope 2)	Electricity	NA	NA	NA	NA	NA	66	70	73	77	81	85
Other Campus	Electricity (Scope 2)	Electricity	NA	NA	NA	NA	NA	7	7	8	8	9	9
TOTAL Electricity (Scope 2)		**Electricity**	**2,149**	**579**	**2,186**	**824**	**320**	**418**	**439**	**461**	**484**	**508**	**533**
Bannatyne Campus	Cooling (Scope 2)	Chilled Water	211	53	232	83	27	54	57	60	63	66	69
Bannatyne Campus	Heating (Scope 2)	Steam	6,379	5,728	5,369	5,854	6,319	6,895	7,239	7,600	7,980	8,378	8,796
TOTAL			**36,875**	**36,851**	**37,244**	**32,602**	**34,277**	**33,257**	**34,916**	**36,658**	**38,487**	**40,407**	**42,422**

Note: Natural gas heating and electricity emissions are divided by campus. Historic data to separate emissions was not available before FY 2013/14. Bannatyne natural gas heating demand is a small fraction of Fort Garry's.

Figure 1. Building GHG emissions by emission source (GgCO2e)



Note: Cooling chilled water emissions are so small they cannot be seen in the figure.

Figure 1 reveals that overall Building GHG emissions have remained fairly steady over time, this despite a significant increase in building area. The baseline projection from FY 2016/17 to 2040/41 indicates that, with assumed increases in student population and faculty and only minor improvements in energy efficiency, overall emissions will increase by approximately 1 per cent per year or an absolute increase of 27 per cent in the next 25 years.

Figure 2 illustrates current FY 2015/16 building emissions by scope and emission source. Direct Scope 1 emissions for building heating account for more than three quarters of Building emissions and Scope 2 steam emissions for heating account for most of the remaing emissions. Cooling and electricity Scope 2 emissions are very small, largely as a result of grid electricity being more than 90 per cent renewable based.

Figure 3 provides additional detail, illustrating building emissions by scope, emission source, as well as by campus.

Figure 2. Current FY 2015/16 contribution of building GHG emissions by scope and emission source

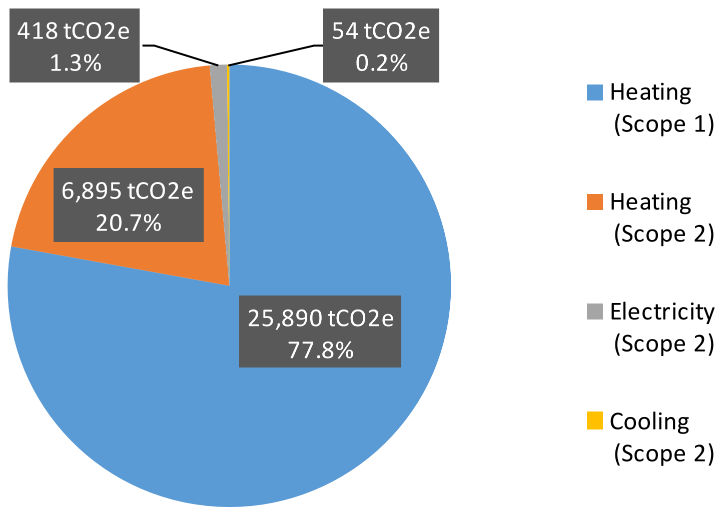
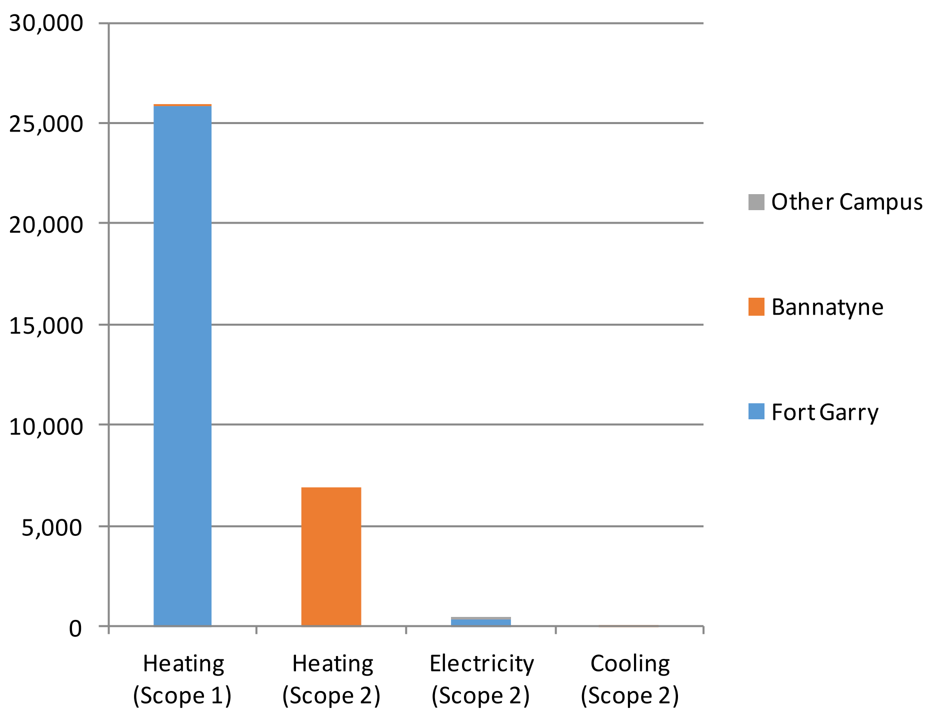
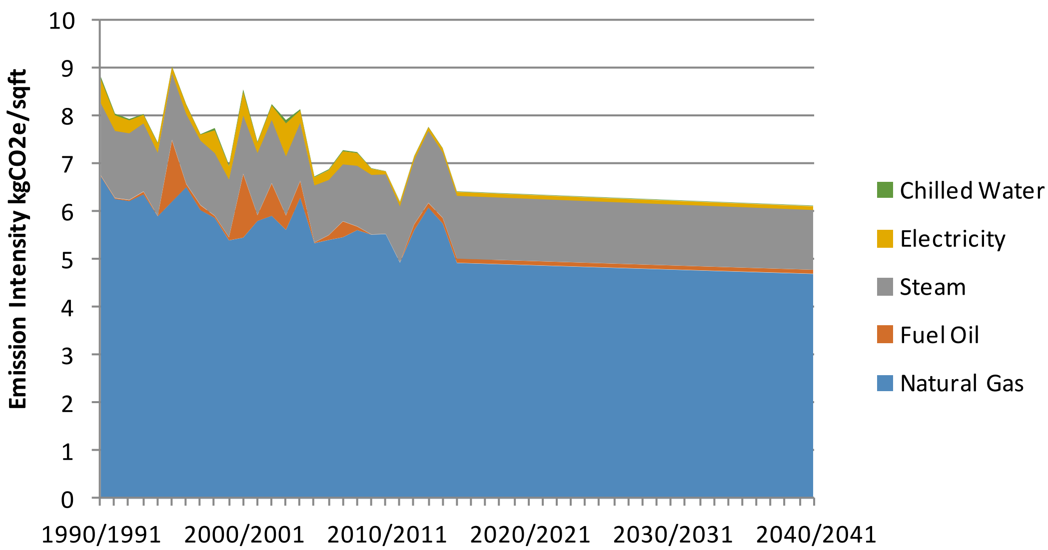


Figure 3. Current FY 2015/16 contribution of building GHG emissions by scope, emission source and campus



Building emission intensity expressed as kg of GHG emissions per square foot ($kgCO_2e$/sqft) is shown over time in Figure 4 and Table 8. Figure 4 indicates that significant progress has been made historically in reducing building emission intensity. Overall building emission intensity has fallen 28 per cent since 1990 or at a rate of 1.3 per cent per year. Projected emission intensities are falling significantly slower at a rate of only 0.2 per cent per year in the baseline. This is partially because significant work to reduce emissions and improve heat production and distribution efficiency has already been undertaken, and without significant new technology and capital investments (not included in the baseline) further efficiency gains are limited.

Figure 4. Building GHG emission intensity by emission source ($kgCO_2e$/sqft)



Note: Cooling chilled water emissions are so small they can't be seen in the figure.

Table 8. Building GHG emission intensity by emission source ($kgCO_2e$/sqft)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Natural Gas	6.73	6.20	5.44	5.33	5.52	4.91	4.87	4.82	4.78	4.73	4.69
Fuel Oil	0.02	1.29	1.33	0.01	0.00	0.09	0.09	0.08	0.08	0.08	0.08
Steam	1.53	1.41	1.24	1.21	1.26	1.33	1.32	1.31	1.29	1.28	1.27
Electricity	0.52	0.14	0.50	0.17	0.06	0.08	0.08	0.08	0.08	0.08	0.08
Chilled Water	0.05	0.01	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	**8.84**	**9.05**	**8.57**	**6.74**	**6.85**	**6.42**	**6.36**	**6.30**	**6.24**	**6.18**	**6.12**

Data Gaps and Uncertainty

The Building emission source category has a few data gaps, primarily related to the difficulty in gathering historic data before FY 2002/03. These data gaps are not likely to affect the results significantly, but could potentially be filled if there was a way to determine how to aggregate and collect older activity data.

Table 9. Summary of data gaps in building sector

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
Fuel oil (litres)	Most recent data from FY 2013/14, 2014/15 and 2015/16 include the amount of fuel delivered to the Physical Plant under contract UofM #C41002 and #C283. It is not clear what the split is for fuel used by the Power House for heating and that used by vehicles. The assumption is that all fuel is used for heating.	Some emissions could be currently allocated to the Building sector where they should be allocated to the Transport sector. While overall emissions would not change significantly, the distribution of emissions between Building and Transport categories could be **significant**.
Purchased steam (lbm)	Purchased steam data is not available before FY 2002/03. Purchased steam load before FY 2002/03 is proportionately estimated based on 2003/04 load and LGS Power House demand in the previous years.	Purchased steam accounts for approximately 20 per cent of overall building emissions so this gap is **significant**.
	The efficiency of the Health Sciences Centre in converting natural gas into steam is an assumption and could be confirmed.	Changes in boiler efficiency may also occur in time that would affect the emission trends. This gap could be **significant**.
Purchased chilled water (tonh)	Purchased chilled water data is not available before FY 2002/03. Purchased chilled water load before FY 2002/03 is estimated based on FY 2003/04 load and relative student and staff population in the previous years.	Purchased chilled water accounts for less than 0.5 per cent of overall building emissions so this gap is **not significant**.

TRANSPORT

Methodology

The Transport emission category includes direct emissions associated with university fleet vehicles fueling at University of Manitoba fuel depots, as well as indirect emissions associated with business related travel, commuting of staff and students to campus and the Fort Garry Campus shuttle service that is operated by a third party. The main transport fuels that are used include both diesel and gasoline.

Table 10. Transport emission sources

Scope	Transport End-Use	Fuel/Energy	Emission Sources
Scope 1	University fleet vehicles	Gasoline (litres), diesel (litres)	University fleet vehicles and equipment fueling at University Fuel Depots
Scope 3	Commuting	Gasoline (litres), diesel (litres)	Personal vehicle, public transit (bus) and carpool
	Shuttle services	Diesel (litres)	Shuttle bus
	Business-related travel	Gasoline (litres), air travel (passenger km)	Air travel, taxi, road passenger vehicle

Historic emissions are calculated by multipling the quantity of fuel or energy consumed during the entire FY with appropriate emissions factors. Projections of future emissions are based on anticipated growth in total student and staff population, as well as assumed changes in vehicle efficiency. The projections do not include a number of university-driven initiatives that may reduce emissions further. The impact of the student bus pass in 2016 is not modelled, nor are the expansion of the rapid transit to the university or the impact of the Active Transporation Path (ATP). These factors are not included in the projection because there is no reliable data yet available to estimate the impact of commuting trips to the university. The impact of these initiatives should be measured in future surveys.

Activity Data and Assumptions

Table 11. Activity data and assumptions used for the transport sector

Type of Activity Data	Transport End-Use	Fuel /Energy	Source of Data	Notes and Assumptions
Historic Activity Data	University fleet vehicles	Gasoline (litres), diesel (litres)	Summary of fuel depot spending reports from Purchasing (2013–2016) • Emails from Jim Tharayil • Statistics Canada historic average gasoline and diesel prices for Winnipeg	Spending is translated to quantities using Statistics Canada price data (Statistics Canada. Table 326-0009 average retail prices for Winnipeg). Spending reports are not for FY periods, so are adjusted to represent 12-month periods.
	Commuting	Gasoline (litres), diesel (litres)	Fuel consumption based on determining passenger km travelled and multiplying by vehicle fuel economy. • total student and staff population (office of institutional analysis) • modal share of transportation, average commuting distance of commute, number of commuting days per year 2014 University Emission Inventory (Office of Sustainability, 2015). • average vehicle fuel economy (United States Bureau of Transportation Statistics). • vehicle occupancy - estimated	Carpool occupancy is estimated at 2.2 persons, which is a typical value that could be verified. Public transit occupancy is estimated at 20 persons. This estimate could be verified in the future to improve commuting GHG estimates.
	Fort Garry shuttle service	Diesel (litres)	Fuel consumption based on total annual mileage and shuttle fuel economy gathered for the 2014 University Emission Inventory (Office of Sustainability, 2015).	Shuttle service is operated by Vital Transit Services. Detailed mileage records or fuel records were not transferred, so estimate is of lower quality.
	Business-related travel	Gasoline (litres), air travel (passenger km)	On-road vehicle fuel consumption based on both mileage combined with average fuel economy, as well as expenditures, combined with fuel prices: • Annual mileage from Purchasing (2012-2016) • average vehicle fuel economy (United States Bureau of Transportation Statistics).	Average vehicle fuel economy based on U.S. data. Canada's passenger vehicle fleet is likely to be similar given harmonized regulations.

Type of Activity Data	Transport End-Use	Fuel /Energy	Source of Data	Notes and Assumptions
			• Statistics Canada historic average gasoline and diesel prices for Winnipeg • Expenditures from fuel cards (statements from Suncor, Imperial Oil and Co-op from purchasing) Air travel passenger km from spreadsheet – Air Carbon Footprint.xls provided by Kristy Hourd from travel services	
Projection Data	All	Student and faculty population	The rate of increased student and faculty population is based on the historic trend over the last nine years and is +1.5 per cent per year. The data was gathered from the Office of Institutional Analysis Enrolment and Academic and Support Staff Reports. http://umanitoba.ca/admin/oia/	Historic growth may not be representative of future growth. Longer-term growth over the last 18 years has been closer to 2.0 per cent.
	All	Gasoline (litres), diesel (litres), air travel (passenger km)	The rate of on-road transportation annual autonomous energy efficiency change was estimated to be -1.7 per cent per year until 2040. The rate of air transportation annual autonomous energy efficiency change was estimated to be -1.4 per cent per year until 2040.	The projected baseline improvement rate in energy efficiency for transporation is driven by efficiency regulations for new vehicles, as well penetration of low emission vehicles.
Emission Factors	All	Gasoline (litres), diesel (litres)	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014.* Part II. Annex 6.	Includes CO_2, N_2O and CH_4 emission factors.
	Business-related travel	Air travel (passenger km)	Overall annual average emission factor per passenger km is from Air Carbon Footprint spreadsheet provided by Kristy Hourd from travel services.	Emission factors vary by type of flight (short, medium, long haul)

Results

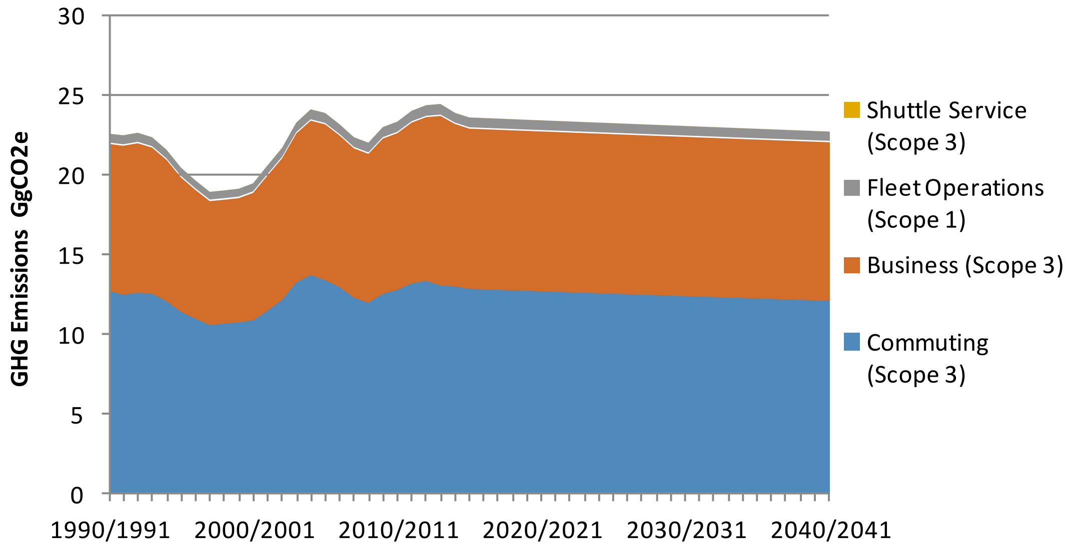
Transport emission sources are related to fuel consumption by vehicles owned directly by the university as well as the operation of vehicles for business-related transport. These emissions overall comprise the second largest emission category of the inventory behind Buildings.

Transport-related emissions are summarized in Table 12 for both direct (Scope 1) and indirect (Scope 3) emission sources. The table presents historic annual emissions starting in FY 1990/91 at five-year intervals until the most recent FY of the inventory 2015/16. Projections at five-year intervals are also presented until FY 2040/41. These emissions and their annual variation are also illustrated in Figure 5.

Table 12. Transport GHG emissions by emission source (tCO_2e)

Emission Source		Historic Emissions						Projections				
		1990 / 1991	**1995 / 1996**	**2000 / 2001**	**2005 / 2006**	**2010 / 2011**	**2015 / 2016**	**2020 / 2021**	**2025 / 2026**	**2030 / 2031**	**2035 / 2036**	**2040 / 2041**
Fleet Operations (Scope 1)	Gasoline and Diesel	558	522	507	632	642	618	666	717	771	830	894
Shuttle Service (Scope 3)	Diesel	3	3	3	4	4	4	5	5	5	6	6
Commuting (Scope 3)	All Commu-ting Types	12,782	11,478	10,935	13,463	12,848	12,902	12,554	12,217	11,888	11,568	11,257
Business (Scope 3)	All Types	9,228	8,430	7,997	9,778	9,835	10,055	10,053	10,054	10,055	10,058	10,063
TOTAL		**22,571**	**20,434**	**19,443**	**23,877**	**23,330**	**23,579**	**23,278**	**22,992**	**22,720**	**22,463**	**22,220**

Figure 5. Transport GHG emissions by emission source ($GgCO_2e$)

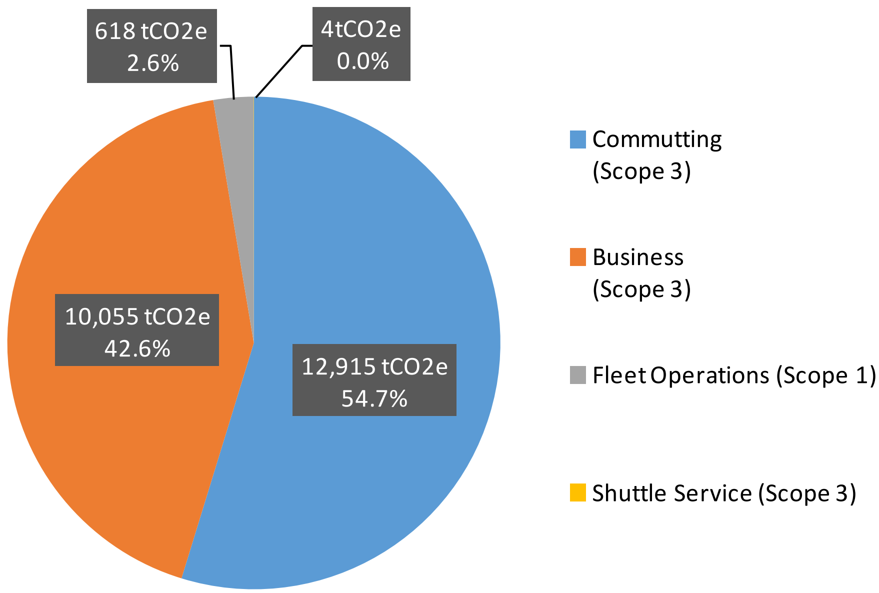


Note: Shuttle service emissions are so small they can't be seen in the figure.

Figure 5 reveals that overall transportation GHG emissions have had small historic variations due to changes in student and faculty population. The baseline projection from 2016/17 to 2040/41 indicates that, even with assumed increases in student population and faculty, overall emissions are expected to decrease by about 0.2 per cent per year due to improvements in fuel economy in the overall fleet of vehicles used by the university. This is an absolute decrease of 5 per cent over 25 years.

Figure 6 illustrates current FY 2015/16 transport emissions by scope and emission source. Direct Scope 1 emissions for fleet operations account for only 2.6 per cent of total transport emissions, whereas, Scope 3 emissions account for the remainder of emissions. The largest emission source is from commuting emissions, followed closely by business travel, where the major contributor is air travel.

Figure 6. Current FY 2015/16 contribution of transport GHG emissions by scope and emission source



Transport emission intensity expressed as kg of GHG emissions per full time student and staff on campus (kgCO_2e/person) is shown over time in Figure 7 and Table 13. The figure indicates that significant progress has been made in reducing transport emission intensity to date. Overall, transport emission intensity has fallen 16 per cent since 1990 or at a rate of 0.7 per cent per year. Projected emission intensities are falling significantly faster, at a rate of 1.6 per cent per year in the baseline. This accelerated decrease in emission intensity is a result of existing stringent fuel economy vehicle regulations and an expected increasing market share of electric vehicles in the future.

Figure 7. Transport GHG emission intensity by emission source ($kgCO_2e$/person)

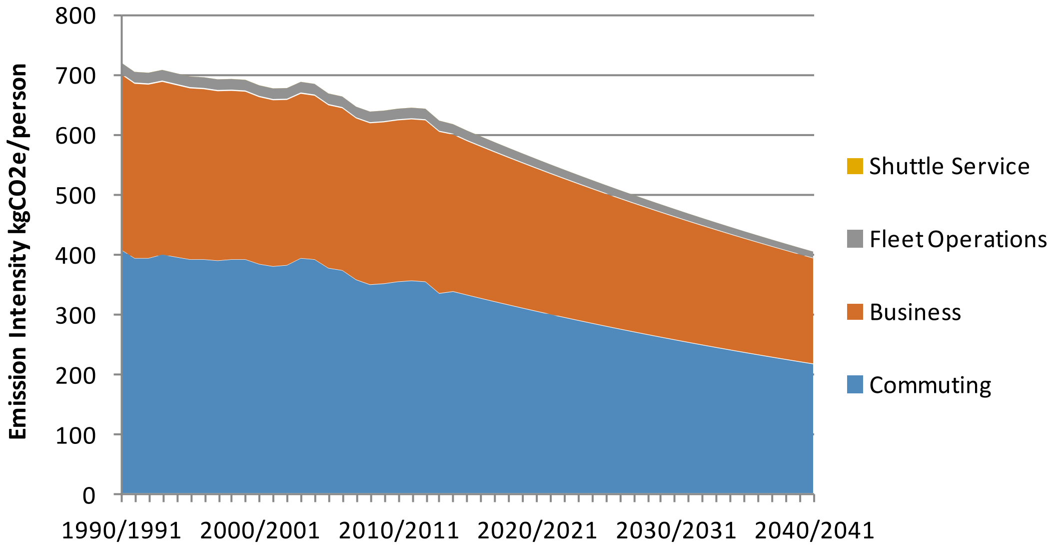


Table 13. Transport GHG emission intensity by emission source ($kgCO_2e$/person)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Commuting	408	392	384	377	354	332	305	280	257	236	216
Business	295	288	281	274	271	258	240	222	206	191	177
Fleet Operations	17.8	17.8	17.8	17.7	17.7	15.9	14.6	13.4	12.3	11.3	10.4
Shuttle Service	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.07
TOTAL	**721**	**697**	**682**	**668**	**643**	**606**	**559**	**515**	**475**	**438**	**404**

Data Gaps and Uncertainty

The Transport emission source category has a few data gaps, primarily related to difficulty in gathering historic data. These data gaps are not likely to affect the results significantly, but could potentially be filled if there was a way to determine how to aggregate and collect some of this old information.

Table 14. Summary of data gaps in transport emission category

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
University fleet vehicles fuel consumption	Fuel suppliers are changed frequently and records preceding 2012 are not readily available from James Tharayil from the Purchasing department. Emissions before this period were based on consumption being directly correlated with historic trend in staff population.	Fleet operations are relatively small compared to the overall inventory and thus the gap is **not significant**.
Commuting	Fuel demand for commuting is currently based on a static modal share from a travel survey that was coordinated by the Office of Sustainability (2014). This modal share is likely changing in time and altering the emission profile. Impacts of the student bus pass 2016, expansion of the rapid transit to the univiersity and the Active Transporation Plan are not currently being considred.	Modal share is based on a single study. Future work should be conducted to see how modal share shifts in time. Assumptions regarding average occupancy and changes in time could have a **significant** impact on the results.
Shuttle service	Fuel demand for the shuttle service is currently based on a static estimate of 20,000 km travelled per year. Future service is projected to expand at the rate of student and staff population projections.	Any significant changes to shuttle service in the future, vehicle type, level of service, number of stops etc. should be captured in future emission inventories. However, the contribution to overall emissions is **not significant.**
Business-related travel	Historic data for business travel before 2012/13 could no be compiled. Emissions before this period were based on consumption being directly correlated with historic trend in staff population.	Business-related travel is driven by air travel (98 per cent of emissions). If significant fluctuations in historic activity of air travel occurred, these are not captured and additional data gathering is recommended. The change in emissions could be **significant**.

AGRICULTURE

Methodology

The Agriculture emission category includes direct emissions associated with processes that are not a result of fuel combustion; rather, they are associated with the raising of livestock, management of manure and crop residues, and the application of synthetic fertilizers. The significant GHGs produced are methane and nitrous oxide. Methane emissions arise from enteric fermentation and manure management associated with livestock. Nitrous oxide emissions arise primarily from synthetic and natural fertilizers (i.e., manure, crop residues) and are based on IPCC assumptions[12] regarding atmospheric deposition and leaching from soils.

Activity data for this sector is sparse as there is no standard practice to maintain records on important agricultural activities such as the population of different livestock year to year, and the purchases and application of synthetic fertilizers. It is likely that the dominant source of emissions are methane and nitrous oxide emissions from enteric fermentation and manure management, which are assessed in this inventory report. Table 15 summarizes the emission sources included. No data on synthetic fertilizer application was collected, but it is believed that these emissions would not be significant. In addition, it was reported that there was no significant practice of burning crop residues that could lead to emissions.

Table 15. Agriculture emission sources

Scope	Agricultural Activity	Emission Sources
Scope 1	Raising of livestock	Enteric fermentation
		Manure management

Historic emissions are calculated by multipling the population of different types of livestock against appropriate emissions factors and in the case of manure management applying factors that also account for the type of livestock management system in place. Projections of future emissions will be dependent on the growth and activities of the University's Agricultural program.

[12] IPCC (2006). *Id. note 8*

Activity Data and Assumptions

Table 16. Activity data and assumptions used for the industrial processes sector

Type of Activity Data	Emission Source	Source of Data	Notes and Assumptions
Historic Activity Data	Enteric fermentation Manure management	Historic livestock populations were provided in the 2013/14 inventory and 2015/16 livestock numbers were reported by University Agriculture expert Tracy Gilson in an email October 11, 2016.	Livestock data before 2014 is unknown and was estimated assuming a direct correlation with historic trend in staff population.
Projection Data	Size and activities of Agricultural Program at University of Manitoba	No data or plans for the Agricultural Program have been included that would suggest either a growth or decline in activities.	The assumption is that in the future the Agricultural Program activities that give rise to GHG emissions will remain static, neither decreasing or increasing.
Emission Factors	Enteric fermentation	2014 Inventory Report	Values are developed by university experts and are reasonable when compared with Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014*, as well as IPCC. While changes in feed and livestock management may affect emissions, it is assumed that there are not significant changes in the baseline.
	Nitrous oxide consumed	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part I. Table 1.1.	

Results

Agriculture emission sources are related to methane emissions from livestock enteric fermentation and from methane and nitrous oxide emissions from the management of manure.

Agriculture emissions are summarized in Table 17. The table presents historic annual emissions starting in FY 1990/91 at five-year intervals until the most recent FY of the inventory 2015/16. Projections at five-year intervals are also presented until FY 2040/41. These emissions and their annual variation are also illustrated in Figure 8.

Table 17. Agriculture GHG emissions by emission source (tCO_2e)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Enteric Fermentation (Scope 1)	540	505	491	616	625	460	460	460	460	460	460
Manure Management (Scope 1)	435	407	395	496	503	891	891	891	891	891	891
TOTAL	**974**	**912**	**887**	**1,111**	**1,129**	**1,351**	**1,351**	**1,351**	**1,351**	**1,351**	**1,351**

Figure 8. Agriculture GHG emissions by emission source (tCO_2e)

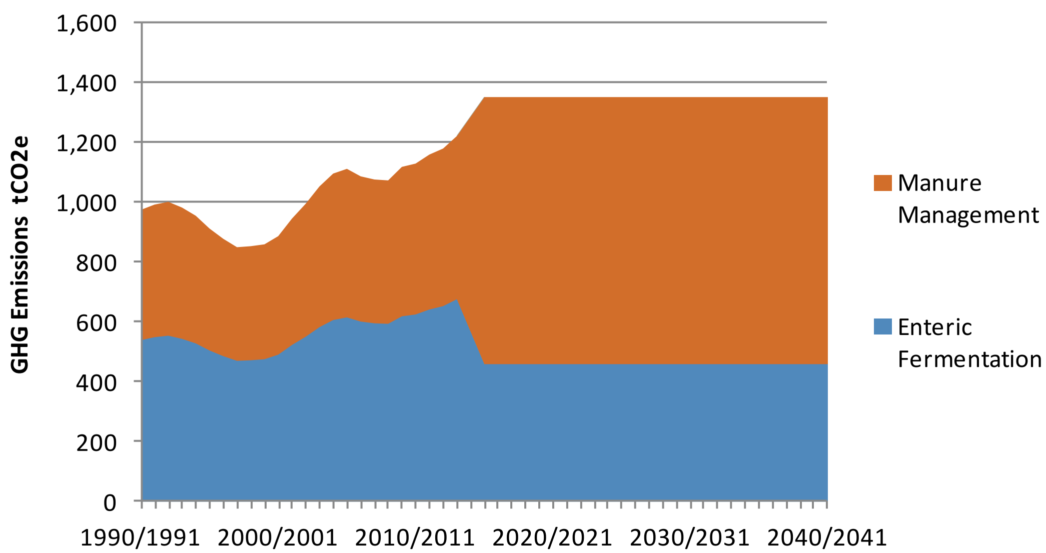


Figure 8 reveals that overall Agriculture GHG emissions are dominated in the future by manure management emissions. The driver of manure management emissions is the number of sows which was reported as 870 in 2015/16. The baseline projection from 2016/17 to 2040/41 indicates that there will be no assumed increases in livestock population and emissions remain static. These emissions are considerably smaller in scope compared to emissions from building and transportation sectors, but still comprise over 3 per cent over overall emissions, albeit shrinking over time in the future.

Data Gaps and Uncertainty

The Agriculture emission source category has two main data gaps. These data gaps are not likely to affect the overall results significantly, unless the university has had very different agricultural operations and livestock holding in the past or is expected to in the future. The gaps could potentially be filled if there was a way identified to collect estimates of historic livestock populations and synthetic fertilizer use.

Table 18. Summary of data gaps in the agriculture sector

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
Livestock Population	Livestock populations are only known for two recent periods: 2014 and 2015/2016. Historic amounts before 2014 are estimated based on a direct correlation of 2014 population to historic changes in student and staff population.	Enteric fermentation and manure management emissions that are calculated from livestock popoulations are **significant** (~4.0 per cent of total direct emissions). However, these types of agriculture emissions are not typically reported by institutions or corporations. Because of the significance of agricultural activities to the university, gathering activity data in the future to monitor these emissions is recommended.
Synthetic Fertilizers	Information on synthetic fertilizers was requested for the project; however, this data could not be obtained.	Quantities of synthetic nitrogen fertilizers that give rise to emissions are **not likely to be significant** (>1 per cent of total direct emissions). It is recommended that emission estimates for the agriculture sector focus only on livestock-related emissions.

INDUSTRIAL PROCESSES

Methodology

The Industrial Processes emission category includes direct emissions associated with processes that are not a result of fuel combustion; rather, they are associated with the use of specific products that can lead to GHG emissions. In the case of the University of Manitoba, only a few processes were identified that could lead to industrial process emissions, including the use of nitrous oxide as an anesthetic for medical purposes and the release of hydrofluorocarbons (HFCs) that are used in air conditioning or refrigeration systems.

HFCs should not be confused with chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs), which are ozone-depleting substances regulated under the Montreal Protocol and substantially phased out in Canada by 2015. HFCs are refrigerants that have primarily replaced these ozone-depleting substances. Regulations to date have focused on the phase-out of these harmful ozone-depleting substances. Because HFCs contribute significantly to GHG emissions, the international community is working hard to find suitable alternative refrigerants that will not contribute significantly to global warming. Carbon dioxide is an example of an alternative low-GHG refrigerant, but it currently has a very low adoption rate and it will take several years before more cost effective alternatives are available.

Table 19 summarizes the emission sources included.

Table 19. Industrial processes emission sources

Scope	Industrial Process	Emission Sources
Scope 1	Refrigerants	Release of HFCs
	Medical Anesthetic	Nitrous oxide consumption

Historic emissions are calculated by multipling the quantity of HFC released or nitrous oxide consumed during the entire FY with appropriate emissions factors. Projections of future emissions are based on anticipated growth in total student and staff population.

Activity Data and Assumptions

Table 20. Activity data and assumptions used for the industrial processes sector

Type of Activity Data	Emission Source	Source of Data	Notes and Assumptions
Historic Activity Data	HFCs released	Leak reports from the University of Manitoba that identify quantity and type of HFC released. Reports provided by the Manitoba Ozone Protection Industry Association.	Note that ozone-depleting substances reported under the Montreal Protocol such as R-22 are not included in the inventory. Some data may be missing or erroneously reported.
	Nitrous oxide consumed	Data on the number of cylinders and weight of N_2O were gathered from supplier Medi-Gas. From this data the total consumption of N_2O per year is estimated.	This is a very small source of emissions: less than 0.01 per cent of total inventory.
Projection Data	Student and faculty population	The rate of increased student and faculty population is based on the historic trend over the last nine years and is +1.5 per cent per year. The data was gathered from the Office of Institutional Analysis Enrolment and Academic and Support Staff Reports. http://umanitoba.ca/admin/oia/	Historic growth may not be representative of future growth. Longer-term growth over the last 18 years has been closer to 2.0 per cent.
	Introduction of alternative low GHG refrigerants	HFCs have largely replaced ozone depleting substances in most equipment. It is expected that HFCs will now slowly be replaced by new alternative low GHG refrigerants such as CO_2 over time.	There are no existing regulations that require the replacement of HFCs; however, they are still likely to occur over time as new equipment is installed. A 2 per cent reduction in emissions per year until 2040/41 is modelled to account for alternative GHG refrigerants.
Emission Factors	HFCs released	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014.* Part I. Table 1.1	Note that some refrigerants are a blend of different HFCs and that the average GWP of the blend is calculated.
	Nitrous oxide consumed	Environment and Climate Change Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990-2014*. Part I. Table 1.1.	

Results

Industrial Process emission sources are related to the use of nitrous oxide as a medical anasthetic and HFCs as a cooling fluid in air conditioning and refrigeration systems.

Industrial Process emissions are summarized in Table 21. The table presents historic annual emissions starting in the FY 1990/91 at five-year intervals until the most recent FY of the inventory, 2015/16. Projections at five-year intervals are also presented until FY 2040/41.

Table 21. Industrial Process GHG emissions by emission source (tCO_2e)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Nitrous Oxide (Scope 1)	2	2	2	2	3	3	2	2	2	2	2
HFC Leaks (Scope 1)	0	0	0	0	0	47	47	45	43	41	40
TOTAL	**2**	**2**	**2**	**2**	**3**	**50**	**49**	**47**	**45**	**44**	**42**

The baseline projection from 2016/17 to 2040/41 indicates that, with assumed increases in the stock of refrigerant appliances, but also with the a low replacement rate of HFC refrigerants for low GHG refrigerants, the overall annual average emissions will decrease by approximately 1 per cent per year. These emissions are very small in scope compared to emissions from building and transportation sectors.

Data Gaps and Uncertainty

The Industrial Process emission source category has two main data gaps that are related to the difficulty in gathering historic data. These data gaps are not likely to affect the results significantly, but could potentially be filled if there was a way to determine how to aggregate and collect some of this older activity data.

Table 22. Summary of data gaps in industrial process sector

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
Nitrous oxide (tonnes)	Amount of nitrous oxide cylinders purchased from Medi-Gas is known for the period between 2011 and 2016. Historic amounts before 2011 are estimated based on the average use for the 2011–2016 period adjusted for the change in student and staff population.	Nitrous oxide emissions are **not significant** (less than 0.1 per cent of total direct emissions) and **it is recommended that they not be included in future inventories**.
HFC (kg)	Reports of leaked HFCs were provided for the time period between 2007 and 2016. It is not clear whether any gaps may occur and there is no data before 2007.	HFC emissions are relatively small, and therefore any possible gaps are **not likely to be significant and could be excluded from future inventories** unless the rate and scale of leaks in HFCS greatly increases in the future.

WASTE

Methodology

The Waste emission category includes indirect emissions associated with the disposal of waste. It includes only emissions related to the breakdown of organic waste in landfills and does not include emissions associated with the collection and transport of wastes. The waste collected on campus is sent to landfill where the organic content of the waste breaks down and produces methane that is either released to the atmosphere or captured by flaring the methan gas or utilizing it for heat or power generation. Table 23 summarizes the emission sources included.

Table 23. Waste Emission Sources

Scope	Waste Process	Emission Sources
Scope 3	Solid Waste Disposal to Landfill	Breakdown of organic wastes to produce methane

Historic emissions are calculated by multipling the quantity of waste collected and sent to landfill for any given year with appropriate emissions factors and parameters that account for the amount of methane ultimately produced. The equation for calculating methane emissions is indicated below. This equation is a standard Tier 1 level methodology reported in various protocols including the IPCC Guidelines[13] and the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories.[14] The formula is simplified in that it assumes that the ultimate methane produced by an amount of waste deposited to landfill in a given year is also released in the same year. In reality there is a significant time delay related to decomposition; however, this simplification is reasonable if there are not very large changes in the amount of waste deposited annually.

$$CH_4\ Emissions = MSW \times MCF \times DOC \times DOC_F \times F \times 16/12 \times (1 - f_{rec}) \times (1 - OX)$$

Where:

MSW = Waste Deposited to Landfill (tonnes)
MCF = Methane Correction Factor (1.0 for managed sites)
DOC = Degradable organic carbon in year of deposition (tonnes C/tonne waste)
DOC_F = Fraction of DOC that is ultimately degraded (%)
F = Fraction of methane in Landfill Gas
16/12 = Stoichiometric ratio between methane and carbon
F_{rec} = Fraction of Methane Recovered at the landfill (%)
OX = Oxidation Factor (%)

[13] IPCC (2006). *Id. note 8*
[14] World Resource Insitutte & World Business Council for Sustianable Development. (2015). *Id. note 2*.

The degradable organic carbon (DOC) is based on the fraction of degradable content for different types of organic wastes (food, garden waste, paper, wood, textiles and industrial waste).

Projections of future emissions are based on anticipated growth in total student and staff population, as well as changes in the amount of methane collected and utilized at the landfill.

Activity Data and Assumptions

Table 24. Activity data and assumptions used for the waste sector

Type of Activity Data	Specific Data Parameter	Source of Data	Notes and Assumptions
Historic Activity Data	Amount of organic waste sent to landfill	The amount of waste sent to landfill is estimated from data provided by the Physical Plant Department and combined with information on the composition of waste to determine the amount of organic waste. • Quantities of total waste from email from Ophelia Morris, Caretaking Services • Data on the composition of organic waste sent to landfill (e.g., food waste, garden waste, paper and product waste) was taken from the University of Manitoba's *Waste Sustainability Report 2014/2015* as summarized in the 2014/15 Emission Inventory.	Waste composition can be significantly different from year to year and the amount of different types of organic waste sent to landfill are based on a single survey result. Every few years these assumptions on the composition of waste should be reviewed through survey methods. Major changes in waste management (e.g., recycling of organic wastes, recycling initiatives) can significantly change the level of methane emissions that can be expected from waste sent to landfill.
Projection Data	Student and faculty population	The rate of increased student and faculty population is based on the historic trend over the last nine years and is +1.5 per cent per year. The data was gathered from the Office of Institutional Analysis Enrolment and Academic and Support Staff Reports. http://umanitoba.ca/admin/oia/	Historic growth may not be representative of future growth. Longer -erm growth over the last 18 years has been closer to 2.0 per cent.
Emission Factors	Methane Correcction Factor, DOC dissimilated, fraction of methane in	Emission factor parameters are taken from Canada's *2016 National Inventory Report for Manitoba.* Environment Canada (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada. Canada's*	

Type of Activity Data	Specific Data Parameter	Source of Data	Notes and Assumptions
	landfill gas, oxidation factor	*Submission to the United Nations Framework Convention on Climate Change.* Part 2. Annex 3 Methodology for Waste Sector.	
	Fraction of methane gas recovered	The fraction of methane gas recovered is from data available from the Brady Road Landfill website and from the University of Manitoba 2013/14 Emission Inventory.	Beginning in 2013/14, methane gas was being recovered from the Brady Road Landfill. The rate of overall recovery is expected to increase to 15 per cent in 2016/17. No further recovery projects are included in the baseline out to 2040. New projects would reduce the overall level of methane emissions.

Results

Waste emission sources are related to the process of disposal of different types of waste that can produce GHG emissions. The waste emission category currently accounts for only 3.3 per cent of total emissions in the inventory.

Waste emissions related to the disposal of organic wastes from the university at the Brady Road Landfill are summarized in Table 25. These emissions are Scope 3 emissions because they do not occur at the University of Manitoba and are not under the management of the university. The table presents historic annual emissions starting in the FY 1990/91 at five-year intervals until the most recent FY of the inventory, 2015/16. Projections at five-year intervals are also presented until FY 2040/41. These emissions and their annual variation are also illustrated in Figure 9.

Table 25. Waste GHG emissions by emission source (tCO_2e)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Solid Waste Disposal (Scope 3)	2,704	2,531	2,461	2,791	2,698	1,418	2,261	2,434	2,620	2,821	3,037

Figure 9. Waste GHG emissions by emission source ($GgCO_2e$)

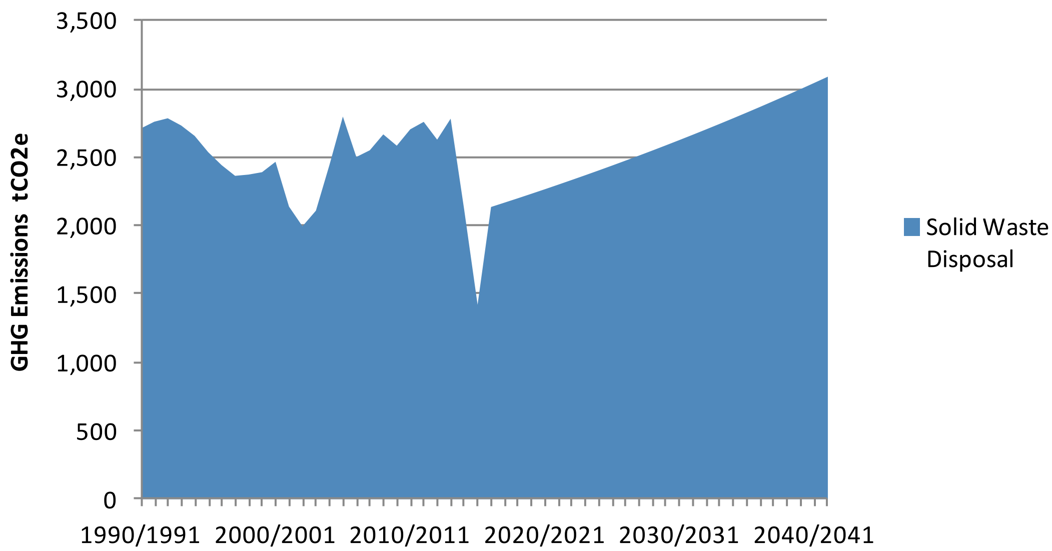


Figure 9 reveals that overall waste GHG emissions have significant annual fluctuations but have remained fairly steady over time until very recently. In 2015/16 there is a significant drop in emissions that is related primarily to the substantially lower volume of waste disposed, but also to the increased rate of methane capture at the Brady Road Landfill. The baseline projection from 2016/17 to 2040/41 indicates that, with assumed increases in student population and faculty and now new improvements in the rate of methane capture, overall emissions will increase by approximately 1.5 per cent per year or an absolute increase of 42 per cent over 25 years.

Waste emission intensity expressed as kg of GHG emissions per population ($kgCO_2e$/person) is shown over time in Figure 10 and Table 26. The figure indicates that significant progress has been made in reducing waste emission intensity. Overall waste emission intensity has fallen 37 per cent since 1990. Projected emission intensities are not falling in time, as the amount of waste deposited to landfill is rising at the same rate as student and staff population and no further improvements in the rate of methane capture are included in the baseline.

Figure 10. Waste GHG emission intensity by emission source (kgCO₂e/sqft)

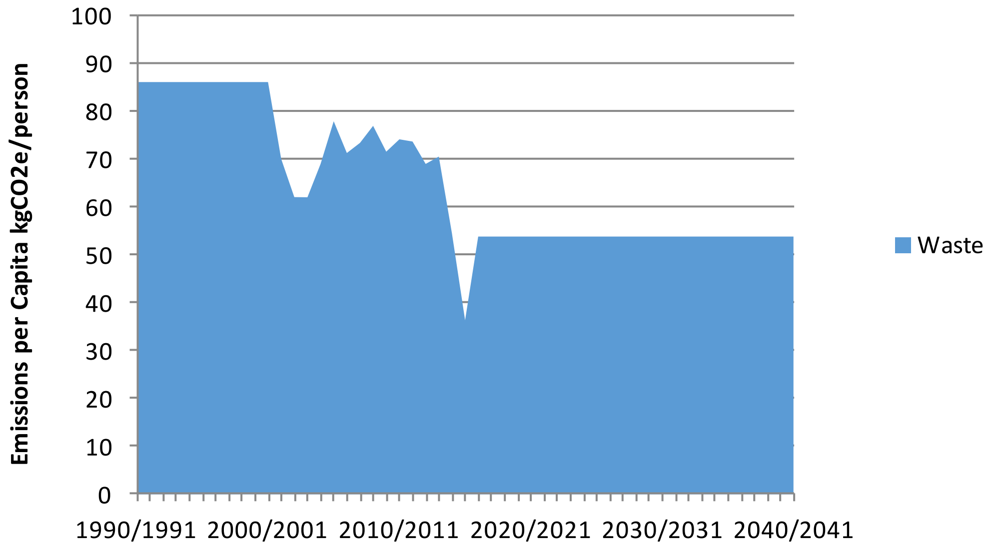


Table 26. Waste GHG emission intensity by emission source (kgCO2e/sqft)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Waste	86.3	86.3	86.3	78.1	74.4	36.5	54.0	54.0	54.0	54.0	54.0

Data Gaps and Uncertainty

Records of waste disposed to landfill from the University of Manitoba have only been collected from the year 2000. This data gap is not likely to affect the results significantly, but could potentially be filled if there was a way to determine how to collect this older activity data.

Table 27. Summary of Data Gaps in Waste Sector

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
Solid waste generated (tonnes)	Estimates of the solid waste generated and sent to landfill were provided for the period 2000/01 to 2015/16. Previous to 2000, data is not currently available and estimates were prepared based on a direct correlation with the number of students and faculty over the same time period.	While annual differences in waste generated before the year 2000 may be significant, the overall trend is **likely not significantly** affected and the estimates are reasonable for considering trends in waste emissions.

EMBODIED PRODUCT EMISSIONS

Methodology

The Embodied Product emission category includes indirect (Scope 3) emissions associated with the life-cycle production and use of products that are purchased and used by the University of Manitoba. Only Embodied Product emissions related to the purchase and consumption of paper were estimated in this inventory report. The emissions were limited to the purchase of virgin paper and predominately recycled paper, as this data was trackable, of sufficient quantity to contribute to significant embodied product emissions and the university has the ability to mitigate these emissions through actions that it can implement. Table 28 summarizes the emission sources included.

Table 28: Embodied Product Emission Sources

Scope	Embodied Product Category	Emission Sources
Scope 3	Paper	Virgin paper
		Mostly recycled paper

Historic emissions are calculated by multipling the quantity of paper purchased in a given year by appropriate emission factors that estimate the amount of energy and GHG emissions associated per unit of production. Projections of future emissions are based on anticipated growth in total student and staff population.

Activity Data and Assumptions

Table 29. Activity data and assumptions used for the embodied product emissions sector

Type of Activity Data	Emission Source	Source of Data	Notes and Assumptions
Historic Activity Data	Embodied paper product	The purchasing department gathered and summarized data on purchases from major suppliers of paper. These suppliers included Grand & Toy and Unisource. The data was only collected for the 11-month period between January 2015 and December 2015.	The assumption is that all paper purchased in a given year was also consumed in that year. While some annual variation may occur, the overall trend is likely to be reasonable. Paper was sub-categorized between virgin paper and predominantly recycled paper (>80 per cent) based on the type of paper indicated.
Projection Data	Student and faculty population	The rate of increased student and faculty population is based on the historic trend over the last nine years and is +1.5 per cent per year. The data was gathered from the Office of Institutional Analysis Enrolment and Academic and Support Staff Reports. http://umanitoba.ca/admin/oia/	Historic growth may not be representative of future growth. Longer-term growth over the last 18 years has been closer to 2.0 per cent.
	Emission intensity of production of paper	The rate of annual autonomous energy-efficiency change for the production of paper was estimated to be -0.5 per cent per year until 2040.	The projected baseline improvement rate in energy efficiency for the production of paper is driven by efforts to reduce GHG emissions at pulp and paper mills. In Canada, pulp and paper mills have already made significant progress in emission reductions. Their ability to continue to achieve large emission reductions is limited so a low rate of improvement is selected for the baseline.
Emission Factors	Embodied paper product	Emission and Energy Production Intensity from University of Bath 2011. Inventory of Carbon & Energy (ICE) Version 2.0 www.bath.ac.uk/mech-eng/sert/embodied	These emission intensities are affected primarily by the fuel type source. Most paper is likely sourced from Canada and most paper mill energy requirements are likely met by biomass and natural gas, which are generally consistent with emission factors from the University of Bath database.

Results

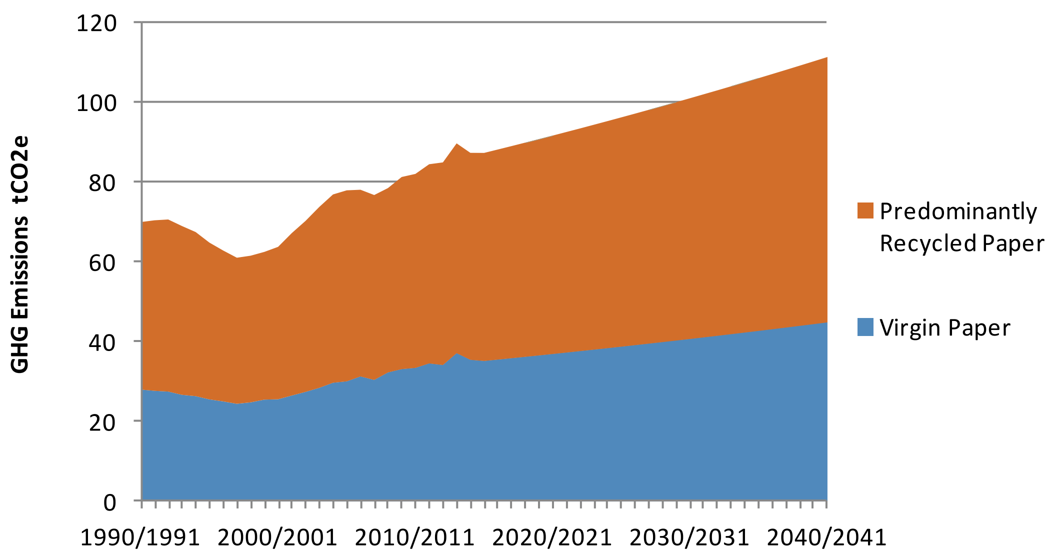
Embodied Product emission sources are related to the purchase and consumption of virgin and recycled paper.

Embodied Product emissions are summarized in Table 30. The table presents historic annual emissions starting in the FY 1990/91 at five-year intervals until the most recent FY of the inventory, 2015/16. Projections at five-year intervals are also presented until FY 2040/41. These emissions and their annual variation are also illustrated in Figure 11.

Table 30. Embodied product GHG emissions by emission source (tCO_2e)

	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Virgin Paper (Scope 3)	28	25	25	30	33	35	37	39	41	43	45
Predominantly Recycled Paper (Scope 3)	42	65	64	78	82	87	91	96	101	106	111
TOTAL	**70**	**90**	**89**	**108**	**115**	**122**	**128**	**135**	**141**	**148**	**156**

Figure 11. Embodied product GHG emissions by emission source (tCO_2e)



Current consumption of paper is about 74 per cent predominantly recycled paper and 26 per cent virgin paper. Figure 11 reveals that overall embodied product GHG emissions are currently approximately 60 per cent from recycled paper and 40 per cent from virgin paper, as a result of the lower emission intensity for recycled paper. The baseline projection from 2016/17 to 2040/41 indicates that, with assumed increases in student population and faculty, overall emissions will increase by approximately 1 per cent per year. These emissions are very small in scope compared to emissions from building and transportation sectors.

Data Gaps and Uncertainty

The Embodied Product emission category has a few data gaps, but they are not expected to have significanty impact. In fact, it is quite clear that from an overall inventory perspective embodied product emissions from paper are not important to track as they are currently a very small contribution to overall emissions (<0.2 per cent).

Table 31. Summary of data gaps in embodied product emissions sector

Data Gap	Description and How Data Gap is Addressed	Notes and Significance
Purchase of virgin and redominantly recycled paper (tonnes)	Data was only available for a recent 11-month period. All data was extrapolated based on student and staff population for the historic period between 1990 and 2014.	Embodied product emissions from paper are very small (0.2 per cent of overall inventory) and variations in historical paper use **would not significantly** affect overall emissions.
Emission factors for virgin and predominantly recycled paper (tCO_2e/tonne)	Emission factors for the production of paper in Canada were unavailable and an international database was used.	Emission factors are from an international database that may or may not appropriately reflect production emissions of paper in Canada. Future work could be conducted to determine the most appropriate life-cycle emission factors for Canadian sourced paper, but it is not likely to have a significant impact on overall emission estimates.

SUMMARY OF RESULTS

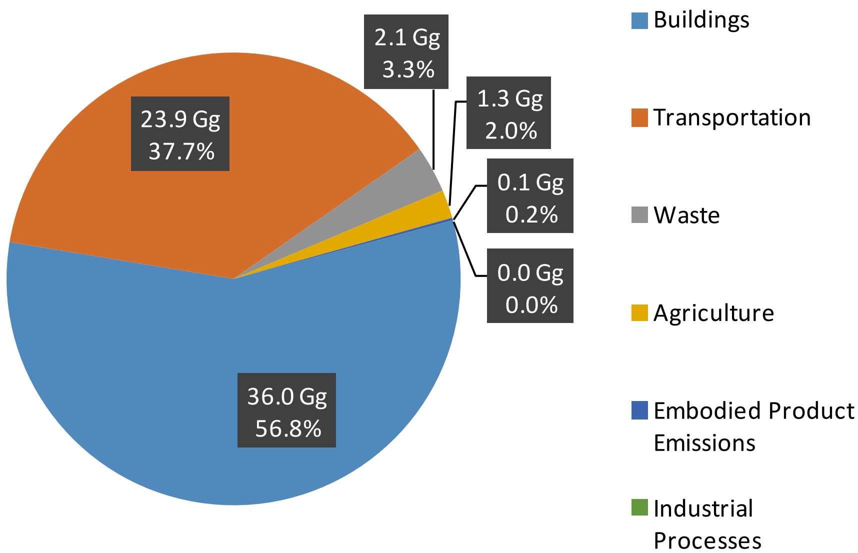
An overall summary of GHG emissions for the University of Manitoba between 1990/91 and 2040/41 is provided in this section. GHG emissions are expressed as CO_2e (carbon dioxide equivalent). The first section presents the results only for the most current FY, 2015/16. The following section presents the results for the entire 1990/91 to 2040/41 period.

Differences between the 2013/14 inventory and this inventory are then highlighted and the last section provideds recommendations for future emission inventory development.

2015/16 Emissions

Total GHG emissions were estimated at 59,790 tCO_2e in 2015/16. This is equivalent to 59.79 Gigagrams or kilotonnes of CO_2e. The sectoral breakout is shown in Figure 12.

Figure 12. Total GHG emissions by emission source category (GgCO2e)



Building emissions comprise more than half of overall emissions, while Building and Transport emissions combined are equal to 94 per cent of total emissions. Waste and Agriculture emission categories contribute a smaller amount of emissions between 2 and 3 per cent. Embodied Product and Industrial Process emission categories contribute emissions that are practically neglibile overall.

In terms of scope, comparing direct (Scope 1), indirect energy (Scope 2) and indirect emissions (Scope 3), almost half of emissions are related to Scope 1 emissions that are primarily related to

Power House emissions. Indirect energy emissions (Scope 2) for building electricity, chilled water and steam are approximately 12 per cent of total emissions. Scope 3 emissions, primarily from Transport, make up the remaining 41 per cent of emissions. Figure 13 illustrates overall emissions by scope, whereas Figure 14 considers the magnitude of emissions by sector and scope in 2015/16.

Figure 13. Total GHG emissions by emission scope ($GgCO_2e$)

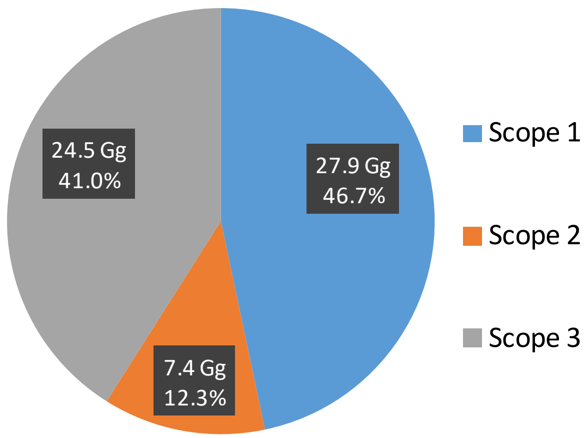
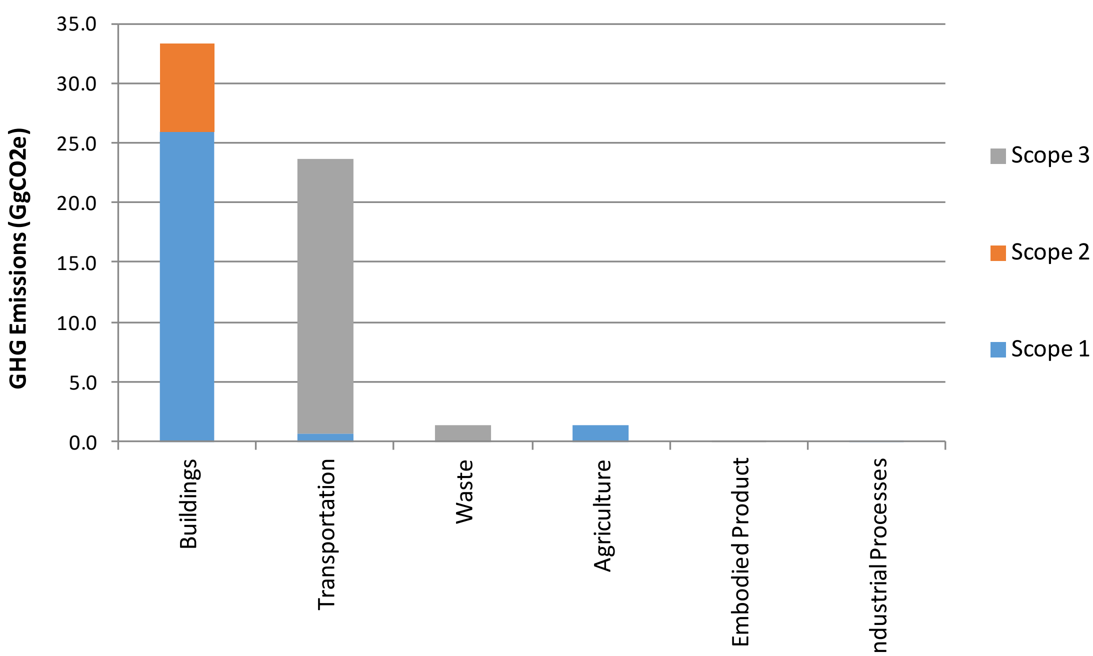


Figure 14. Total GHG emissions by sector and emission scope ($GgCO_2e$)



Embodied Product and Industrial emissions are so small relatively that they barely show up in the graph; Scope 1 Building emissions and Scope 3 Transportation emissions are the most significant emission sources.

All emission sources can be ranked in terms of overall emission contributed. Table 32 highlights the ranking and emission contribution from individual emission sources for each of the emission categories.

Table 32. Ranking of importance of emission sources to overall contribution in 2015/16

Category	Sub-Category / Emission Source	Scope	Fuel / End-Use	Rank	Emissions (tCO_2e)	% of Total
Buildings	Heating	Scope 1	Natural Gas	1	25,444	42.6%
Transportation	Business	Scope 3	Air Travel	2	9,835	16.4%
Transportation	Commuting	Scope 3	SOV	3	8,574	14.3%
Buildings	Heating	Scope 2	Steam	4	6,895	11.5%
Transportation	Commuting	Scope 3	Public Transit	5	3,332	5.6%
Waste	Solid Waste Disposal	Scope 3		6	1,418	2.4%
Transportation	Commuting	Scope 3	Carpool	7	1,010	1.7%
Agriculture	Manure Management	Scope 1		8	891	1.5%
Transportation	Fleet Operations	Scope 1		9	618	1.0%
Agriculture	Enteric Fermentation	Scope 1		10	460	0.8%
Buildings	Heating	Scope 1	Fuel Oil	11	446	0.7%
Buildings	Electricity	Scope 2	Electricity	12	418	0.7%
Transportation	Business	Scope 3	Vehicle Travel	13	219	0.4%
Embodied Product Emissions	Embodied Paper Products	Scope 3	Predominantly Recycled Paper	14	87	0.1%
Buildings	Cooling	Scope 2	Chilled Water	15	54	0.1%
Industrial Processes	ODS Substitutes	Scope 1		16	47	0.1%
Embodied Product Emissions	Embodied Paper Products	Scope 3	Virgin Paper	17	35	0.1%
Transportation	Shuttle Service	Scope 3		18	4	0.0%
Industrial Processes	Nitrous Oxide	Scope 1		19	3	0.0%

Building energy use (mainly natural gas) is the number one emissions source, while Scope 3 Transportation emissions are also major sources of emissions, taking the second, third, fifth and seventh place in the rankings. After Buildings and Transportation, the next major emission category is Waste. Methane emission from the disposal of organic waste to landfill is the sixth largest emission source and accounts for 2.4 per cent of overall emissions. Agricultural emissions are also significant, with manure management and enteric feremenation ranked at eighth and 10th largest emission sources in 2015/16. Emissions related to Embodied Product emission and Industrial Process emissions are not significant and ranked at the bottom.

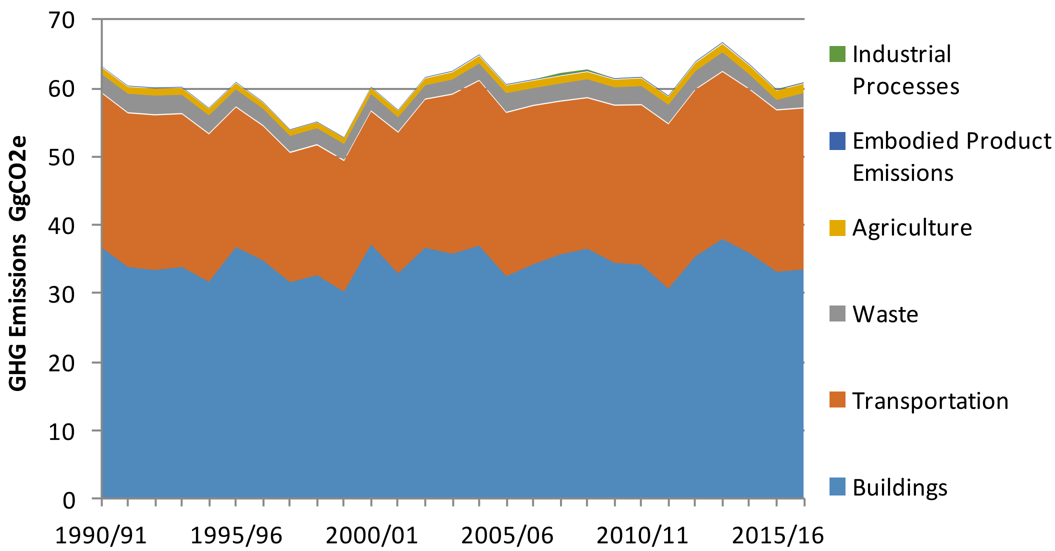
Despite the fact electricity consumed by the University of Manitoba is almost exclusively from hydropower and non-emitting energy, there is a small amount of emissions still associated with electricity. This can include the use of coal or natural gas in times of emergency, or a need to import power in times of shortage. Total emissions in 2015/16 related to electricity consumption is less than 1 per cent of total emissions. In fact the emission factor for electricity, tCO_2e/MWh of electricity consumed considers that less than 5 per cent is from non-renewable sources.

Identifying the contribution of emissions overall in this way is useful in the development of the low-carbon options as it helps identify priority emission sources to address GHG mitigation activity.

Baseline Emission Projection

Historic emissions were identified for the period 1990/91 to the current fiscal period under consideration, 2015/16. These emissions are shown in Figure 15.

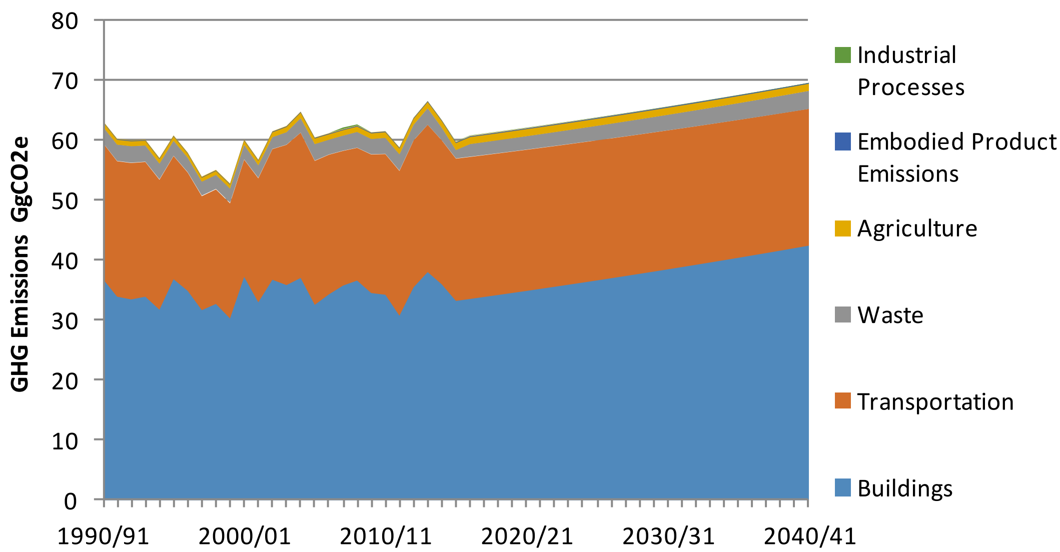
Figure 15. Historic GHG emissions by emission source category ($GgCO_2e$)



Note: Industrial process and embodied product emissions are so small they cannot be seen in the figure.

Baseline emissions were also projected out to 2040/41, which are shown in Figure 16.

Figure 16. Projected GHG emissions by emission source category (GgCO₂e)



Historic and projection emissions for every five years during the period are summarized in Table 33.

Table 33. GHG emissions by emission source category ($GgCO_2e$)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Buildings	36.9	36.9	37.2	32.6	34.3	33.3	34.9	36.7	38.5	40.4	42.4
Transportation	22.6	20.4	19.4	23.9	23.3	23.6	23.4	23.2	23.1	22.9	22.7
Waste	2.70	2.53	2.46	2.79	2.70	1.42	2.26	2.43	2.62	2.82	3.04
Agriculture	0.97	0.91	0.89	1.11	1.13	1.35	1.35	1.35	1.35	1.35	1.35
Embodied Product Emissions	0.07	0.09	0.09	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.16
Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.04	0.04
TOTAL	**63.2**	**60.8**	**60.1**	**60.5**	**61.6**	**59.8**	**62.1**	**63.9**	**65.7**	**67.6**	**69.7**

Figure 15 and 16 reveal that, historically, emissions have been relatively stable, declining in some years and rising in other years, but essentially at the same level in 2015/16 as they were in 1990/91. This indicates that, despite significant growth on campus and more students and university staff, emissions have been stable. Baseline projections show overall emissions increasing by approximately 0.6 per cent per year on an annual basis or by 17 per cent in absolute terms over the next 25 years.

Overall projected emission intensity is summarized in Figure 17 and Table 34. The overall emission intensity is expressed as the total GHG emissions divided by the total expected student and staff population in $kgCO_2e$/person.

Figure 17. Projected GHG emission by intensity ($kgCO_2e$/person)

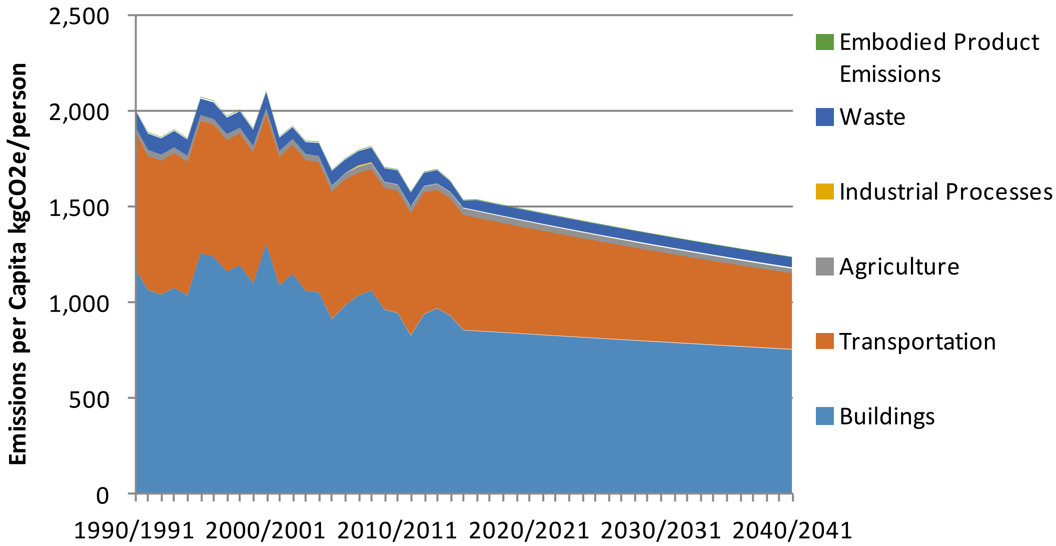


Table 34. Projected GHG emission by intensity ($kgCO_2e$/person)

Emission Source	Historic Emissions						Projections				
	1990/ 1991	1995/ 1996	2000/ 2001	2005/ 2006	2010/ 2011	2015/ 2016	2020/ 2021	2025/ 2026	2030/ 2031	2035/ 2036	2040/ 2041
Buildings	1,178	1,257	1,307	913	945	855	834	813	793	773	754
Transportation	721	697	682	668	643	606	559	515	475	438	404
Agriculture	31.1	31.1	31.1	31.1	31.1	34.7	32.2	30.0	27.8	25.8	24.0
Industrial Processes	0.07	0.07	0.07	0.07	0.07	1.28	1.17	1.04	0.93	0.84	0.75
Waste	86.3	86.3	86.3	78.1	74.4	36.5	54.0	54.0	54.0	54.0	54.0
Embodied Product Emissions	2.23	3.07	3.13	3.02	3.18	3.14	3.06	2.99	2.91	2.84	2.77
TOTAL	**2,018**	**2,075**	**2,110**	**1,693**	**1,696**	**1,537**	**1,483**	**1,416**	**1,353**	**1,295**	**1,239**

It is important to recognize from Figure 17 that significant progress in reducing the emission intensity of University of Manitoba activities has been achieved historically and that these improvements are still expected overall in the future baseline. Historical average emission intensity has fallen from a peak of 2,075 $kgCO_2e$/person in 1995/96 to a current level of 1,537 $kgCO_2e$/person in 2015/16. This represents a decrease of 25 per cent in emission intensity. In the future, this trend is expected to continue and the emission intensity in 2040/41 is projected to fall to 1,239 tCO_2e/person, a further decrease of 19 per cent from 2015/16.

Differences between the IISD Team GHG Inventory and the Previous University of Manitoba GHG Inventory

An emission inventory was prepared for the FY 2013/14 with the support of the Office of Sustainability. The emission inventory guide that was published was critical to the preparation of this report as it helped to define scope and identified important activity data and methodologies. There are a number of differences, some minor and some fundamental between our approach in this report and the 2013/14 inventory. Significant differences are identified in Table 35.

Table 35. Differences between the 2013/14 inventory and this inventory

Sector / Emission Source	Why are Emissions Different then in 2013/14 Inventory?
All Sectors	The 2014 inventory uses GWP values of 28 for CH_4 and 265 for N_2O. This is inconsistent with Canadian reporting and the national inventory, which uses 25 for CH_4 and 298 for N_2O.
Buildings – Natural Gas	2013/14 inventory appears to include external customers on campus. External customers were not included as they are not under the control of the university.
Buildings – Electricity	Unclear why consumption data is nearly double (208 GWh vs. 107 GWh) available data that was identified. Electricity emission factors were corrected to represent generation emission factors as opposed to consumption emission factors (there are transmission losses that increase the consumption emission factor).
Buildings – Steam	Emissions double counted (emissions of one boiler running on natural gas and a second boiler running on fuel oil), not adjusted for per cent operation (99 per cent natural gas vs. 1 per cent fuel oil). The efficiency of the Health Sciences Centre boiler that provides indirect heat was also not included in original calculation.
Transportation – Commuting	Mileage of public transit bus was not corrected for passenger km. So estimates of emissions from public transit were at least 10 times too high (we have assumed average passenger numbers to be 20 persons). Overall the commuting emissions were a factor of two or more too high.
Transportation – Air Travel	Mileage of 129,655,214 km included mileage from two other years (actual mileage identified was only 43,737,408 km). However, the emission factor was 50 per cent too low, so the resulting effect is emissions were 32 per cent lower.
Industrial Processes	Emissions from N_2O and HFCs were not included in the 2013/14 inventory.
Embodied Product Emissions	Embodied product emissions from paper were not included in the 2013/14 inventory.

Recommendations

The key areas for inventory improvement are related to activity data collection and institutional capacity to prepare and develop future inventories.

1. An institutionalized approach to inventory preparation with set timetables, documentation methods and quality assurance/quality control (QA/QC) procedures will be far more successful then ad-hoc, non-scheduled projects to develop new inventories.
2. The emission inventory ideally needs a lead embedded in the Office of Sustainability at the university that understands the basic tools (e.g., emission inventory and baseline projection tool), methods and data that have been used in past inventory work, and who is primiarly responsible for the collation and preparation of future inventories. This need not be a significant appointment that requires substantial resources, as others can share the burden of preparing the inventory; however, it does require that someone undersands all aspects of the inventory work and that they have committed resources. A very rough estimate of resources would be 150–200 hours per year.
3. A central accessible database that holds key documents and all activity data with clear references is critical for both archiving and sharing the emission inventory with the team.
4. A management organizational chart should be developed to identify the University of Manitoba staff and departments that are expected to contribute to the inventory in the future. This chart could also ideally identify contributions from specific individuals and departments.
5. Collecting inventory data is a time-consuming process. The more this process can be streamlined and standardized, the fewer resources will be ultimately expended in the future. Identification of the source of data and methods for gathering and preparing the data are important. The inventory database is organized by emission source category and key documents and spreadsheets are identified in this inventory report. Providing templates or previous examples of submissions of activity data is useful. Data gatherers who are familiar with the ultimate results of the inventory will inherently have a better understanding of what is required, so it is recommended that a brief summary of the synopsis be shared with them.
6. Important updates to the inventory that are recommended to be conducted periodically include:
    a. Every few years a commuting modal share transport study should be completed to assess how transport mode choices change and vehicle occupancy rates are changing. This is especially important because of the recent Student Bus Pass implementation and the expansion of rapit transit to the university.
    b. Every few years a waste study should be conducted to determine the composition of the waste that is diverted and sent to landfill. Most important is the per cent by mass composition of organic waste that is sent to landfill divided into paper/textile waste, garden/park waste, food waste and wood/straw waste categories. In addition, the fraction of methane captured/utilized at the Brady Road Landfill in the future should be monitored.
    c. Total student and staff population is a very important driver of future emissions in the model and should be updated annually.

7. It is recommended that the following emission sources be excluded from future inventories, as their contribution to overall emissions is neglibile (<0.1 per cent):
    a. Industrial Process nitrous oxide emissions
    b. Transportation Shuttle Service emissions
    c. Industrial Process HFC emissions
    d. Building Indirect Cooling emissions from chilled water

ANNEX A: GUIDE TO THE EMISSION INVENTORY AND BASELINE PROJECTION TOOL

Introduction

This Annex provides instructions on how to update and use the emission inventory and baseline projection tool to create future inventories and projections for the University of Manitoba. The emission inventory and baseline projection tool was developed specifically for the University of Manitoba and allows users to enter activity data, emission factors and information about projection drivers in order to estimate emissions from sources in six emission categories: buildings, transportation, agriculture, industrial processes, waste and embodied product emissions.

The instructions provided are intended to allow a user to navigate and update the tool, as long as there are not significant changes in the emission sources on campus. Adding new emission sources is possible but may require additional knowledge and expertise in GHG inventory development.

The tool was designed to determine a single future emission projection to establish a baseline scenario between today and FY 2040/41, indicating what emissions can be expected from the university without additional actions on climate change. The primary aim of the baseline is to provide a scenario from which to consider impacts of potential mitigation actions and also to measure progress of the university towards meeting future targets.

The tool could easily be adapted to consider alternative emission scenarios, and look at "what if" scenarios composed of different actions on climate change. A module of the tool allows a user to calculate emission reductions over time related to a specific mitigation option and consider it against the baseline.

Background

There are many considerations when selecting a tool to develop an emission inventory and projection for an institution such as the University of Manitoba. Off-the-shelf tools exist, but they can be less versatile and are not set up to consider specific emission sources and circumstances of importance to the University of Manitoba.

In order to be effective for the University of Manitoba, an emission inventory and baseline projection tool should have the following characteristics:

1. **Simple to use** – users with a moderate knowledge of emission inventories can update and use the inventory
2. **Adaptable and flexible to the data available** – consistent with data format (time, unit, etc.)
3. **Transparent** – clear where data is coming from, and calculations can be back-calculated
4. **Complete** – includes all of the emission sources of concern
5. **Easy to update –** a user with minimal training can update the emission inventory with new available data
6. **Low cost and resource intensive –** requires minimal time to produce necessary outputs
7. **Meets requirements for reporting –** by the Office of Sustainability and in the future by others

With these aspects in mind, IISD has developed a simple accounting emission projection model in Microsoft Excel. The tool can be used without any additional software requirements and does not require expert knowledge of Microsoft Excel.

Tool Methodology

The spreadsheet tool implements methods and conducts all the calculations that are described in this emission inventory report and are consistent with inventory guidelines, including emission inventory guidelines such as the *2006 IPCC Guidelines*[15] and estimation methodologies used to estimate emissions for *Canada's National Inventory Report*.[16] In their most basic form, emissions are estimated by multiplying some type of activity data by an appropriate emission factor. As an example, emissions from gasoline used in fleet operations in 2014/15 are calculated as follows:

$$Emissions_{GHG} = Activity\ Data \times Emission\ Factor_{GHG}$$

[15] Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories.* Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[16] Environment Canada. (2016). *National Inventory Report 1990–2014: Greenhouse gas sources and sinks in Canada*. Canada's Submission to the United Nations Framework Convention on Climate Change. Retrieved from https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=662F9C56-1

$$Emissions_{GHG} = 125{,}746\ litres\ of\ gasoline \times 0.002326\ tCO2e/L$$

$$Emissions_{GHG} = 292\ tCO2e$$

The specific Excel worksheets included in the tool and their purpose are identified in Table A1.

Table A1. Baseline emission projection tool hierarchy of building worksheets and emission sources

Worksheet Type	Worksheet	Purpose
Background	Version – Updates	Provides version and update tracking tables, to identify updates and when they were completed
	Model Structure and Guidance	Provides some basic instruction on how the tool is organized and the basic steps to using the tool
Sector Category Worksheets	Building – Direct Energy	Scope 1: emissions associated with buildings
	Building – Electricity	Scope 2: indirect emissions from electricity
	Building – Indirect Energy	Scope 2: indirect emissions from steam and chilled water
	Transportation	Scope 1: direct and 3 indirect emissions from vehicles
	Agriculture	Scope 1: emissions from livestock
	Industrial Processes	Scope 1: emissions from nitrous oxide and HFCs
	Waste	Scope 3: emissions from wastes sent to landfill
	Embodied Product Emissions	Scope 3: emissions from paper use
Supporting worksheets	GWP	Identifies appropriate global warming potentials for different GHGs
	Projection Drivers	Identifies projected annual change in emissions based on drivers such as population, campus building area and changes in energy efficiency
	Summary	Provides data tables and figures that summarize trends in total emissions as well as emission intensity
	Mitigation	Calculations and visualization of potential mitigation options and resultant emission reductions from baseline

All GHGs are combined into one aggregate unit called carbon dioxide equivalent (CO_2e). The carbon dioxide equivalent is calculated using the 100-year global warming potentials for specific gases that are identified for use in Canada's latest National Inventory Report.[17] Global warming potential (GWP) is a relative measure of the warming effect that the emission of a radiative gas (i.e., a GHG) might have on the surface atmosphere and was developed to allow a comparison of the ability of each GHG to trap heat in the atmosphere relative to carbon dioxide. The GWP used in the tool are indicated in the **GWP** Worksheet.

Projections are based on the expected change over time in the activity or in the emission factor. The tool uses a simplified approach that relates emissions to specific annual drivers such as growth in population, projected building area and changes in average energy efficiency and demand. The projection drivers are developed in the Projection Drivers worksheet. These drivers

[17] Ibid.

indicate the per cent annual change that can be associated with a specific emission source or emission factor. Note that it is possible to combine multiple projection drivers into one. For example, for a given emission source, we could have a driver for demand that is increasing and a driver for efficiency that is reducing emissions. Their combined impact is calculated as follows:

$$Annual\ \%\ Change\ in\ Emissions_{Combined} = \left(\%\ Change_{Driver\ 1} + 1\right) \times (\%\ Change_{Driver\ 2} + 1) - 1$$

A separate worksheet is provided for every emission source category: ***Buildings***, ***Transportation***, ***Agriculture***, ***Industrial Processes***, ***Waste*** and ***Embodied Product Emissions***. The Buildings category is also broken down into three separate worksheets that examine direct energy use, electricity use and other indirect energy use (i.e., steam and chilled water).

Each of the eight emission source category worksheets have a similar design and use four different tables that are described below.

Table A2. Data tables in each of the emission source category worksheets

Table #	Name	Purpose
1	Activity Data Table	Historical Activity data in specified units for every fiscal year (FY)
2	Emission Factors Table	Relevant emission factors related to each emission source for every FY including projections
3	Calculation of Emissions Table	Activity Data is combined with Emission Factors to calculate carbon dioxide equivalent emissions for the entire historical and projection period
4	Summary of Emissions Table	Emission data is read from Table 3 to produce figures that can be used to visualize emission trends overtime

The individual worksheets use a hierarchy to identify individual emission sources. This hierarchy depends on the sector. For example, Building direct energy emission sources can be identified by fuel type, building and campus. Transportation sources can be identified by fuel type, transport sector (e.g., fleet operations, shuttle service, commutting and business travel), as well as end-use (e.g., vehicle type). All emission sources that are entered should fit within this hierarchy. Additional rows are available in each table to enter new data for new emission sources.

The spreadsheet uses colour-coded cells to indicate different types of data that can be entered into cells. Other cells in the spreadsheet are protected and should not be changed by the user, unless there is a need to change the methodology of calculation or to add new features. The protection of the spreadsheet is controlled in the Review Tab under Protect Sheet—the password to unprotect the sheet is ***UofM Inventory***. The colour codes are described in Table A3.

Table A3. Colour codes used in the tool worksheets

(green)	Green denotes cells where user input is permitted to enter activity data or to select parameters.
(yellow)	Yellow denotes cells where the user may consider entering new information (e.g., new emission sources, new emission factors) but doing so requires unprotecting the worksheet.
(orange)	Orange denotes cells that are projections and not based on historic activity data. These cells should not be modified unless substantial changes in methodology are required.

Five Basic Steps in Using The Tool

Step 1: Identify emission source

Any emission source of concern should be related to one of the eight emission source category worksheets. Here we need to identify if the emission source is already included or a new emission source needs to be added by reviewing the appropriate worksheet. If an emission source needs to be added, each table will need to include appropriate/unique description names in columns B, Ca nd D. These columns can identify fuel type, building, type of livestock, end use, etc., depending on the emission source of concern. Be careful to disaggregate emission data as much as possible, within existing sources, without becoming too burdensome.

Step 2: Enter historic activity data (Table 1)

The activity data should be in the units indicated in column F for each emission source. Column G can be used to convert data units to the units used by the model (e.g., convert from m3 of natural gas to GJ). Historic data is always entered in the same column for a given year. Column AH corresponds to the fiscal year 2016/17. Be careful when changing old historic data: why have the numbers changed?

Step 3: Check/enter corresponding emission factors (Table 2)

Emission factors express tonnes of GHG emissions per unit of activity in Table 1. The unit of activity may be converted using column G. Where possible, each GHG should be included,and aggregated into CO2e using GWP in GWP worksheet.

Step 4: Check/enter projection drivers (Table 3)

Table 3 summarizes activity data, emission factors and then calculates the emissions in tCO_2e for each emission source. In column G, the name of a projection driver that corresponds to the name of a projection driver in column B of the projection driver worksheet can be used for activity data. New emission sources can be added in subsequent rows.

Step 5: Check/generate figures & output (Table 4 & Summary worksheet)

In Table 4, enter the appropriate emission sources of interest (columns B, C and D). Beside the figures that plot both historic emissions as well as baseline projections you can indicate if you want to modify the units and identify the appropriate Y-axis. Additional emission intensity graphs and overview graphs are generated in the summary worksheet.

Data Collection

A Dropbox folder created by IISD and shared with the university is currently being used to store all the inventory data in one location and allow direct access by the inventory team. This folder should be moved and set up on university servers to provide open access to those who will need it.

The Dropbox inventory data folder is organized into the following sub-folders that align with the emission source categories:

- Agriculture
- Embodied Product Emissions – Paper
- Buildings – Energy
- Industrial Processes
- Transportation
- Waste

Wherever possible, original activity data from logs, receipts and accounting were collected. Many of the source files are in their original formats, such as Microsoft Excel, but some are scanned PDF files, archived Outlook email files and JPEG images.

Important Tips When Updating the Tool

1. **Spelling matters.** The spreadsheet uses lookup functions to pull data from different tables for the calculations. The most popular form of lookup function is an excel function named =SUMIFS(range to sum, criteria range 1, criteria 1, criteria range 2, criteria 2,…). For this lookup function to work, the criteria must be the exact spelling and have no extra spaces. Without the correct spelling, the function will usually return zero.
2. **Currently there are no external links to other spreadsheets.** It may be tempting to create external links to other spreadsheets that have activity data or emission factors, but these links can end up being a problem in the long run, especially as new data becomes available or data gets replaced. We would advise against creating external links; instead check data carefully when entering or pasting values into the spreadsheet.
3. **Always update version numbers and dates on the tool file name**
4. **Always include the source of data when entering new information.**
5. **Do not insert new columns or rows unless necessary.** Columns with data values always align to specific fiscal years, column H through BF, are aligned to FY 1990/91 through 2040/41.
6. **Standard units in the spreadsheet are tonnes of carbon dioxide equivalent and Gigajoules (energy).** It is important that the correct conversions are provided beside activity data so that emission factors match the activity data. For plotting data, adjustment modifiers are provided in the figures to convert to kilotonnes CO_2e if this is preferred.

Buildings

The hierarchy of emission sources currently included in the Buildings worksheets is shown in Table A4 below.

Table A4. Baseline emission projection tool hierarchy of building worksheets and emission sources

Worksheet / Category	Scope	Emission Source		
		Level 1	Level 2	Level 3
Building - Direct Energy All direct combustion fuel use associated with buildings	***Scope 1***	***Fuel Type*** Natural Gas, Fuel Oil	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***Campus*** Fort Garry or Bannatynne Campus
Building - Electricity Indirect electricity consumption	***Scope 2***	***Electricity Source*** Manitoba Hydro	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***Campus*** Fort Garry or Bannatynne Campus
Building - Indirect Energy Indirect steam and chilled water consumption	***Scope 2***	***Indirect Source*** Steam, Chilled Water	***Building(s)*** Individual or groups of buildings on Fort Garry or Bannatynne Campuses	***Campus*** Fort Garry or Bannatynne Campus

Transportation

The hierarchy of emission sources currently included in the Transportation worksheet is shown in Table A5 below.

Table A5. Baseline emission projection tool hierarchy of transportation worksheet and emission sources

Worksheet / Category	Scope	Emission Source		
		Level 1	Level 2	Level 3
Transportation Direct and indirect transport fuel consumption consumption	***Scope 1*** (fleet operations) ***Scope 3*** (commuting, shuttle service, business travel)	***Fuel*** Gasoline, diesel, jet fuel	***Transport Subsector*** Fleet operations, commuting, shuttle service, business travel	***End-Use*** For commuting end use divided into single occupancy vehicle, transit and carpool. for business travel divided between air and vehicle travel

Agriculture

The hierarchy of emission sources currently included in the Agriculture worksheet is shown in Table A6 below.

Table A6. Baseline emission projection tool hierarchy of model worksheets and emission sources

Worksheet / Category	Scope	Emission Source	
		Level 1	Level 2
Agriculture Emissions arising from agricultural activities	***Scope 1***	***Emission Source*** Enteric fermentation, manure management	***Activity Data*** Type of livestock

Industrial Processes

The hierarchy of emission sources currently included in the Agriculture worksheet is shown in Table A7 below.

Table A7. Baseline emission projection tool hierarchy of industrial processes worksheet and emission sources

Worksheet / Category	Scope	Emission Source	
		Level 1	Level 2
Industrial Processes Emissions arising from non-combustion activities on campus	***Scope 1***	***Emission Source*** Nitrous oxide, ozone depleting substances (HFCs)	***Activity Data*** Nitrous oxide bulk purchase, HFCs

Waste

The hierarchy of emission sources currently included in the Waste worksheet is shown in Table A8 below.

Table A8. Baseline emission projection tool hierarchy of waste worksheet and emission sources

Worksheet / Category	Scope	Emission Source	
		Level 1	Level 2
Waste Emissions arising from waste management	***Scope 3***	***Emission Source*** Solid waste disposal	***Activity Data*** Solid waste generated

Embodied Product

The hierarchy of emission sources currently included in the Embodied Product worksheet is shown in Table A9 below.

Table A9. Baseline emission projection tool hierarchy of embodied product worksheet and emission sources

Worksheet / Category	Scope	Emission Source	
		Level 1	Level 2
Embodied Product Emissions Emissions arising from the production of products purchased by the University of Manitoba	***Scope 3***	***Emission Source*** Embodied paper products	***Activity Data*** Virgin paper, predominantly recycled paper, paperboard

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