GHG INVENTORY REPORT

Year 2012

BISHOP'S UNIVERSITY GREENHOUSE GASES INVENTORY REPORT

Presented to :

Mr. Michel Caron, director of Buildings and Grounds Services

By :

Enviro-access GHG Experts

December 2013

Bishop's University Greenhouse Gases Inventory Report

BASE-YEAR 2012

Bishop's University greenhouse gases (GHG) emissions inventory was prepared according to the requirements of the *International Standard ISO 14064-1:2006*. The scope of this GHG inventory includes the activities of Bishop's University as well as the following GHG sources category: stationary combustion equipment, mobile equipment, air conditioning and refrigeration units, production of consumed electricity, business and home-to-school travel of employees as well as students by bus or car, production of consumed fossil fuels, landfilling waste, recycling of recyclable materials, composting of organic waste, production of office paper, mobile equipment used for transport of waste and paper, treatment of drinkable and waste water.

The total of Bishop's University GHG emissions for the base-year 2012 – 1st of January through 31st of December – is 6,728 tonnes of CO_2e.

Enviro-access inc.

Place Andrew-Paton
85 North, Belvedere (suite 150)
Sherbrooke, (Qc), J1H 4A7
Tel. 819.823.2230
www.enviroaccess.ca

Summary

Located in the heart of the Appalachian Mountains and surrounded by rich green spaces and wildlife, Bishop's University has always been at the forefront to conserve and protect its beautiful surroundings. Throughout the years, the University displayed its commitment to adopt a sustainable lifestyle by the creation of numerous related committees and policies, and by the establishment of a new Sustainable Development Office.

This greenhouse gases emission (GHG) Inventory aims to improve the campus sustainability by providing an accurate evaluation of the GHG emissions related to the University facilities and activities. This declaration will help to identify the main GHG sources and work efficiently toward their reduction.

In total, the activities related to Bishop's University have generated 6,728 tCO_2e in 2012, which are divided into the following: 2,504 tCO_2e of direct emissions, 18 tCO_2e of energy indirect emissions and 4,206 tCO_2e of other indirect emissions.

The items included in the inventory are buildings, motorized equipment, the University community travels, waste management, wastewater treatment, paper consumption, water consumption, and fossil fuel production.

The results for the 2012 GHG inventory show that students and staff travels are the most important item in terms of GHG emissions. This traveling accounts for 2,658 tCO_2e, which is equivalent to approximately 40 % of total GHG emissions.

The other two elements that are responsible for a significant part of total GHG emissions from Bishop's University are the buildings and the fossil fuels production. These two elements represent 2,461 tCO_2e (approximately 37 % of the total) and 1,302 tCO_2e (approximately 19 % of the total). In regard to buildings, the combustion of natural gas used primarily for space heating is the principal source of emissions (95 %) with 2,380 tCO_2e.

This GHG inventory was prepared according to the requirements of the *International Standard ISO 14064-1:2006*.

This GHG inventory report includes:

- ✓ Building heating and cooling systems and their energy consumption (fossil fuel and electricity)
- ✓ Use of motorised mobile equipment (fossil fuel)
- ✓ Students and staffs travels (fossil fuel)
- ✓ Waste management (Landfilling, valorisation, and transport)
- ✓ Office paper consumption (production and transport)
- ✓ Drinkable water treatment (production)
- ✓ Wastewater treatment (treatment and electricity use)

The following tables and figures present the GHG inventory results for 2012 Bishop's University activities.

TABLE 1: 2012 BISHOP'S UNIVERSITY GHG INVENTORY RESULTS PER SOURCES AND CATEGORIES

EMISSION TYPES	SOURCES	CO_2 EMISSIONS (t CO_2)	CH_4 EMISSIONS (t CH_4)	N_2O EMISSIONS (t N_2O)	HFC EMISSIONS (t HFC)	GHG EMISSIONS (t CO_2e)	CONTRIBUTION TO SUB-TOTAL EMISSIONS	CONTRIBUTION TO TOTAL GHG EMISSIONS
Buildings								
Direct	Fossil fuel combustion	2,364.43	0.05	0.05	-	2,379.95	80.16 %	35.38 %
Direct	Refrigerant leaks in air conditioning systems	-	-	-	0.039	63.69	2.15 %	0.95 %
Direct	Leaks of gaseous CO2 in University's laboratories	-	-	-	-	0.02	0.001 %	0.0004 %
Direct	Combustion of acetylene	-	-	-	-	0.10	0.004 %	0.002 %
Indirect energy	Electricity production and consumption	17.26	0.002	0.001	-	17.63	0.59 %	0.26 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	507.60	17.10	7.55 %
	SUB-TOTAL	***2,381.69***	***0.05***	***0.05***	***0.039***	***2,969.00***	***100 %***	***44.13 %***
Motorised mobile equipment								
Direct	Fossil fuel combustion	57.35	0.02	0.002	-	58.53	75.44 %	0.87 %
Direct	Refrigerant leaks in air conditioning systems	-	-	-	0.001	1.85	2.38 %	0.03 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	17.20	22.17 %	0.26 %
	SUB-TOTAL	***57.35***	***0.02***	***0.02***	***0.001***	***77.58***	***100 %***	***1.15 %***
Landfilling, recycling, composting and transportation of waste								
Other indirect	Landfilling, recycling and composting of waste	43.65*	5.06	0.03	-	139.91	94.59 %	2.08 %
Other indirect	Fossil fuel combustion (transportation of waste)	6.08	0.0003	0.0003	-	6.19	4.18 %	0.09 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	1.80	1.22 %	0.03 %
	SUB-TOTAL	***6.08***	***5.06***	***0.03***	***-***	***147.91***	***100 %***	***2.20 %***
Students and employees transportation								
	Fossil fuel combustion	2,632.93	0.14	0.07	-	2,658.09	77.42 %	39.51 %

	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	775.60	22.59 %	11.83 %
	SUB-TOTAL	***2,632.93***	***0.14***	***0.07***	-	***3,433.70***	***100 %***	***51.04 %***

*Production and transport of office paper***

Other indirect	Production of office paper	-	-	-	-	38.29	99.77 %	0.57 %
	Fossil fuel combustion	0.07	0.000003	0.000004	-	0.07	0.18 %	0.001 %
	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	0.02	0.05 %	0.0003 %
	SUB-TOTAL	***0.07***	***0.000003***	***0.000004***	-	***38.38***	***100 %***	***0.57 %***

Drinkable water production

Other indirect	Drinkable water production	-	-	-	-	2.65	100 %	0.04 %
	SUB-TOTAL	-	-	-	-	***2.65***	***100 %***	***0.04 %***

*Wastewater treatment****

Other indirect	Wastewater treatment	-	-	0.19	-	58.22	99.79 %	0.87 %
	Energy consumption of wastewater facilities	0.12	0.00001	0.00001	-	0.12	0.21 %	0.002 %
	SUB-TOTAL	***0.12***	***0.00001***	***0.19***	-	***58.34***	***100 %***	***0.87 %***
	TOTAL	**5,078.37**	**5.27**	**0.34**	**0.04**	**6,727.54**	**-**	**100 %**

* Not included CO_2 emissions since they are from biomass.
** CO_2, CH_4 and N_2O emissions data include only consumed paper transport. CO_2e emissions data are for production and transport.
*** CO_2, CH_4 and N_2O emissions data are from the electricity consumption at the wastewater treatment facility.

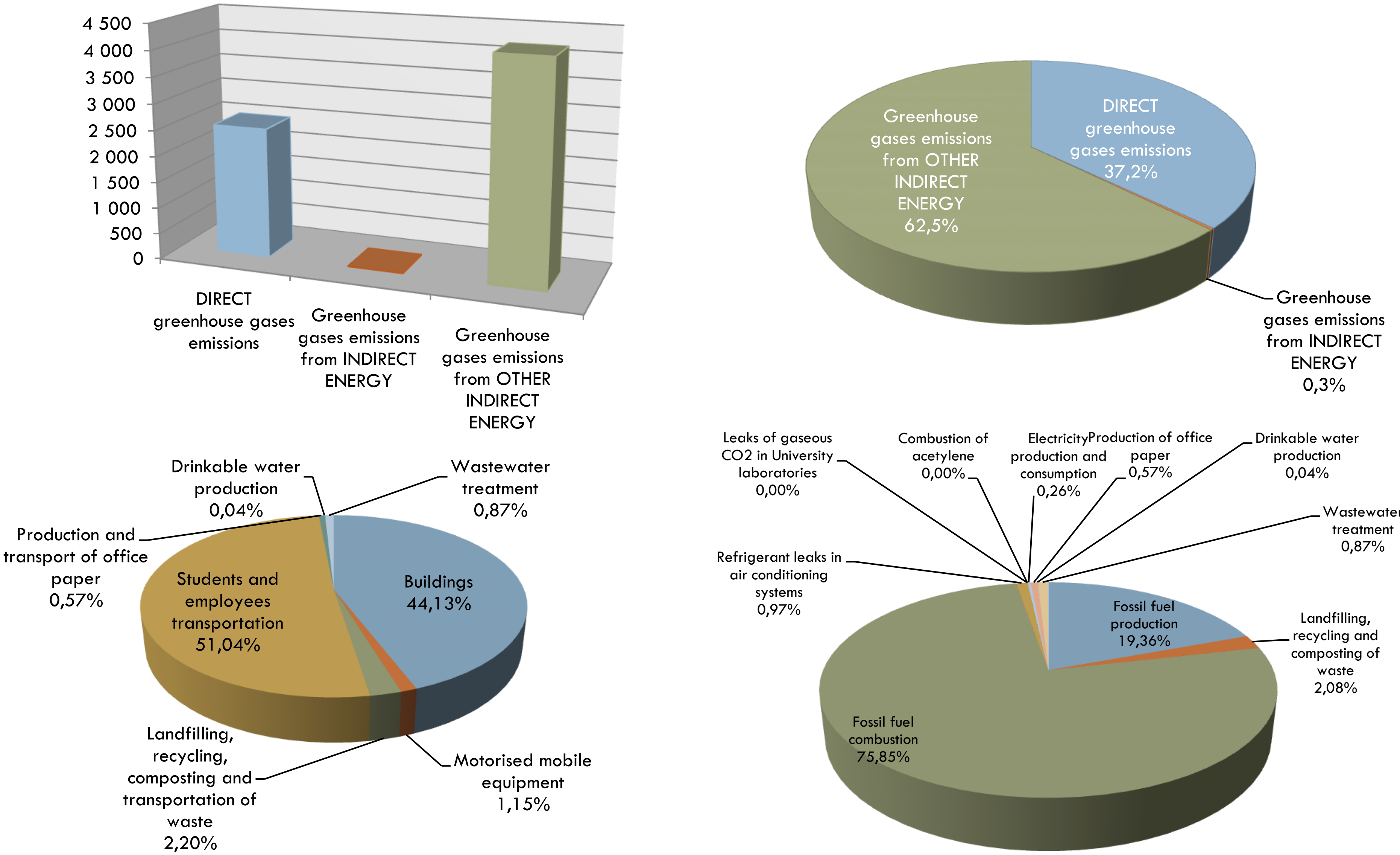
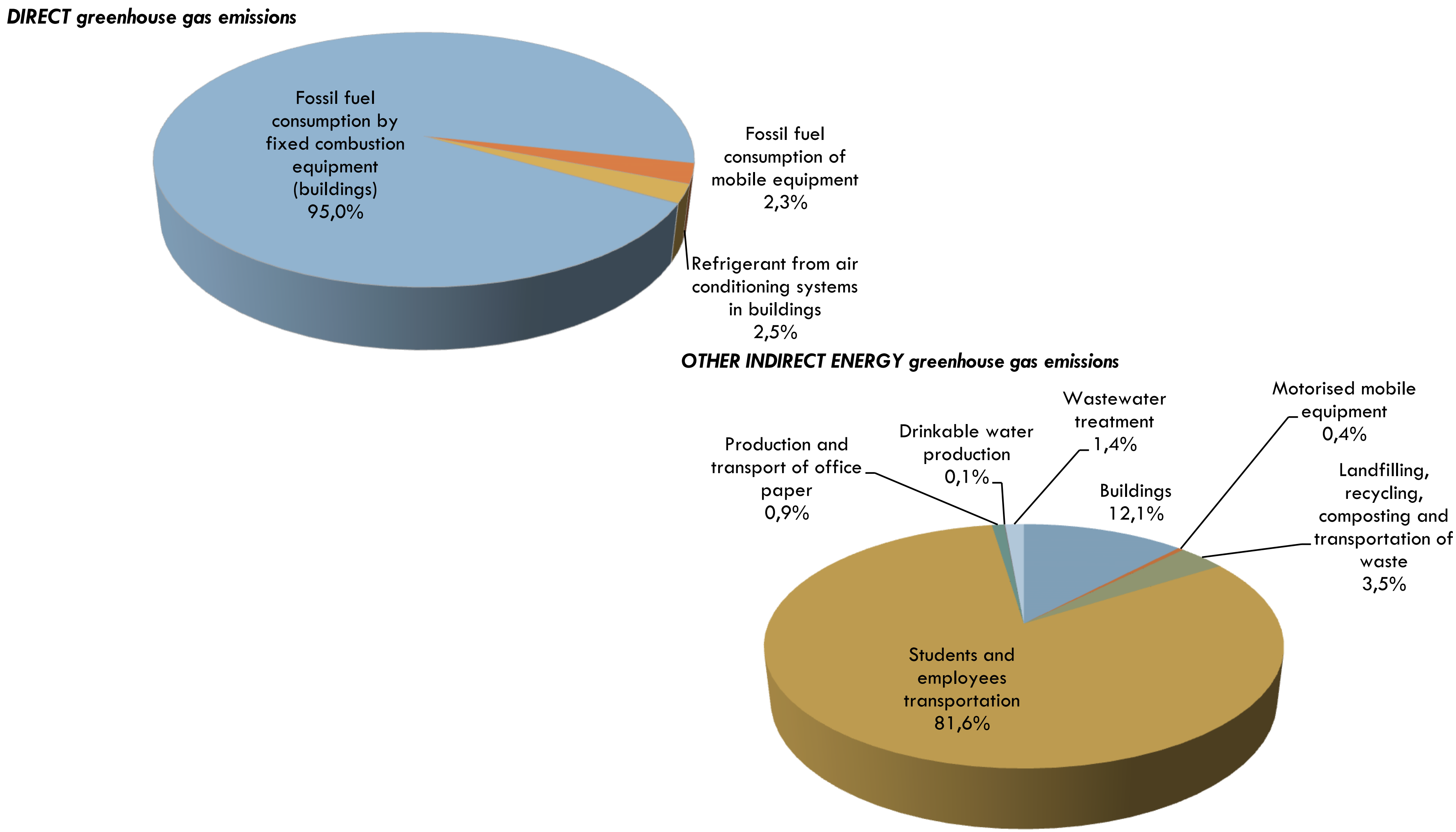


FIGURE 1: SUMMARY OF GHG EMISSIONS PER CATEGORY AND SOURCES



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Bishop's University Greenhouse Gases Inventory Report

BASE-YEAR 2012

INTRODUCTION

Located in the heart of the Appalachian Mountains and surrounded by rich green spaces and wildlife, Bishop's University has always been motivated to conserve and protect its beautiful surroundings. Throughout the years, the University has demonstrated its commitment to adopt a sustainable lifestyle with the creation of numerous related committees and policies, and by the establishment of a new Sustainable Development Office.

This GHG Inventory aims to improve the campus sustainability by providing an accurate evaluation of the GHG emissions related to the entire University facilities and activities. This report will help to target the principal GHG sources and work efficiently toward their reduction.

1 GHG INVENTORY OBJECTIVES

This GHG Inventory plan contains several objectives. Not only it will ensure annual tracking of the University's emissions, but it will also allow to elaborate a GHG Reduction Action Plan with adaptable, realistic, and measurable targets. More specifically, the GHG Inventory aims to:

- Establish GHG reduction objectives and follow the University performance throughout the years
- Identify GHG reduction opportunities
- Identify potential GHG projects
- Communicate results to the university's community and general public
- The opportunity to register to many voluntary action programs including GHG registries

2 GHG INVENTORY DESCRIPTION

2.1. Description of the Reporting Organization

Enviro-access inc. is a non-profit organization (NPO) in business since 1993 to support innovation and improvement of best practices for the environmental field. Enviro-access began developing its expertise in greenhouse gas reduction projects in early 2000. Today, our team is considered one of the most experienced in Canada in the quantification of GHG emissions, the identification of mitigation measures, to support the preparation of projects to reduce GHG emissions, as well as the validation and verification of projects and GHG inventories. Enviro-access has carried out more than 100 project plans for GHG emission reductions, project information notes (PIN), and inventories of greenhouse gas emissions for industrial, institutional, and municipal clients.

Enviro-access also provides customized training on best practices in energy management and pollution prevention for municipalities, companies, institutions, and other groups. Our team of experts has developed and given hundreds of hours of training in various fields.

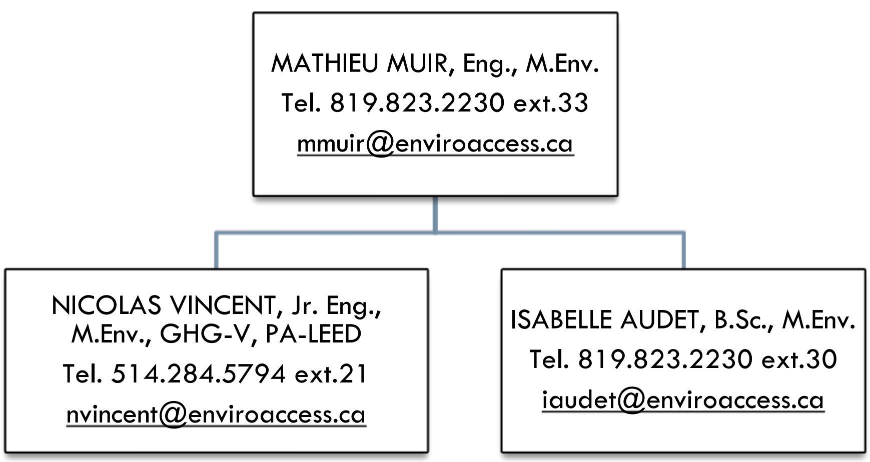
From the 70 municipalities and Regional County Municipalities (RCMs) doing business with Enviro-access through the Climat municipalités program, more than 50 GHG inventories have been completed and approved by the MDDEFP (Quebec environment department), including inventories for two Regional Council of Municipalities (RCMs), and 30 action plans have been submitted to that program. Through this experience, the team developed some 300 potential actions of GHG reduction in various fields, i.e. energy efficiency, reduction in drinking water use, landfill diversion, reduction in fuel use, improvement in public transit services and many more.

Enviro-access is among the few firms accredited by the Standards Council of Canada as a validation and verification body under the Greenhouse Gas Accreditation Program. Combined with our technical expertise and experience, this status brings a significant advantage to our clients towards the credibility of their greenhouse gas emissions' inventory or project.

ENVIRO-ACCESS INC.
85 North, Belvedere (Suite 150)
Sherbrooke (Québec) J1H 4A7
Tel. 819.823.2230
Fax 819.823.6632
info@enviroaccess.ca www.enviroaccess.ca

2.2. Realization Team

The realization of this GHG Inventory was conducted by Mathieu Muir Eng., Lead Project Manager at Enviro-access. Nicolas Vincent Jr, Eng. and Isabelle Audet B.Sc, M.Env, both technical advisors at Enviro-access, were the technical support team in this project. All documentation was subject to thorough quality verification according to our quality control internal protocol.



2.3. Responsible Team in Bishop's University

Mr. Michel Caron, Director of the Buildings and Grounds Services, was the lead project manager at Bishop's University. Ms. Angela Lanza, Sustainable Development Student Intern, assisted Mr. Caron in the data collection.

Mr. MICHEL CARON	Ms. ANGELA LANZA
Director, Buildings and Grounds Services	Sustainable Developement Student Intern
Bishop's University	Bishop's University
Tel. 819.822.9600,poste 2549	Tel. 819.822.9600, poste 2195
mcaron@ubishops.ca	SDSI@ubishops.ca

2.4. Time Period

This document presents the GHG emissions Inventory of the Bishop's University occurring between January 1st, 2012 and December 31st, 2012.

2.5. Organizational Boundaries

The GHG Inventory includes all GHG emissions issued from the use of buildings and fixed and motorised equipment present on the main campus, in Lennoxville, Quebec.

The GHG emissions were consolidated according to a control approach. Thus, all GHG emissions and removals from facilities over which Bishop's University has financial or operational control were taken into account.

2.6. Operational Boundaries

Definition of the operational boundaries began by identifying all GHG sources that the University wished to include in its inventory. Then after, those were subdivided into three different categories:

- **DIRECT GHG EMISSIONS** are emissions issued from sources directly controlled by the Bishop's University, such as stationary combustion equipment used for building heating and mobile equipment used for University activities.
- **ENERGY INDIRECT EMISSIONS** are emissions issued from electricity production, or from the imported heat or vapor consumed in the buildings and equipment operation, provided by an external entity (sources out of the organizational boundaries).
- **OTHER INDIRECT GHG EMISSIONS** are emissions issued from the main campus activities but from sources controlled by external enterprises, such as waste disposal (transport and processing) and the transportation means of students and employees.

The *Greenhouse Gas Protocol*[1] and the *International Standard ISO 14064-1* recommend that the reporting organization quantifies, minimally, GHG emissions from direct and energy indirect categories (scope 1 and 2 in the *Greenhouse Gas Protocol)*. These must be included in the GHG inventory.

GHG emission sources and categories for this GHG Inventory are presented in table 1. Some GHG sources were excluded since they account for non-significant GHG emissions, as well as quantification was technically non doable (lack of data). Excluded GHG sources are:

1. <u>Elimination process of hazardous materials:</u> No information is available regarding the elimination process of hazardous materials.

2. <u>Production and transport of food:</u> Bishop's cafeteria is operated by subcontractors. Since the mass of consumed food is not available for 2012, this source is not included in this GHG quantification. However, as the origin of each food product is generally known, this source could be quantified with a future monitoring of consumed food quantities.

3. <u>Production and transport of maintenance products:</u> Responsibility of buildings maintenance belongs to a subcontractor. Origins and quantities of maintenance products used by this enterprise were not disclosed for 2012. This source is excluded from this GHG inventory.

Since Bishop's University does not burn biomass in its operations, no GHG emission can be associated with biomass combustion in this inventory.

Nevertheless, waste material degradation emits CO_2 emission from biomass. According to the ISO 14064-1, this type of GHG emissions must be quantified but should not be included in the total of the GHG inventory. In fact, when waste materials are composed in part by organic materials, CO_2 emissions from incineration or degradation are not considered. In this actual case, those CO_2 emissions from biomass were estimated to 43.7 tCO_2e.

Table 2-1 shows the complete list of GHG sources included in this GHG inventory quantification.

[1] **World Ressources Institute ; World Business Council for Sustainable Development. 2004**. A Corporate Accounting and Reporting Standard (Revised Edition). s.l. : WBCSD, c/o Earthprint Limited, 2004.

TABLE 2-1: GHG EMISSIONS SOURCES

Sources	Components	Description
DIRECT greenhouse gases emissions		
Fossil fuel combustion (heating oil, gasoline, diesel, natural gas, propane)	Fossil fuel consumption by fixed combustion equipment (buildings)	Includes all activities involving fossil fuel combustion (oil, diesel, natural gas and propane) in buildings from defined operational boundaries. Natural gas and heating oil are used for building heating. Diesel is used by emergency diesel generator. Propane is used in BBQ Grills systems.
	Fossil fuel consumption of mobile equipment	Includes all activities involving mobile equipment, defined by operational boundaries, where gasoline and diesel combustion occurs.
Refrigerant leaks in air conditioning systems (R404a, R409a, R410a, R414b, R134a)	Refrigerant from air conditioning systems in buildings	Includes all activities involving the use of refrigerants (R404a, R409a, R410a and R414b) in buildings from defined operational boundaries. Refrigerant emissions are principally from leaks in air conditioning systems and from the system production and elimination (filling and disposition of the refrigerant).
	Refrigerant from air conditioning systems in vehicles used by the university and sub-tractors	Includes all activities involving the use of refrigerants R134a in mobile equipment from defined operational boundaries. Refrigerant emissions are principally from leaks in air conditioning systems and from the system production and elimination (filling and disposition of the refrigerant).
Combustion of acetylene	Combustion of acetylene	Includes all activities involving the combustion of acetylene from defined operational boundaries. Acetylene is principally used in soldering while gaseous
Leaks of gaseous CO_2 in University's laboratories	Use of gaseous CO_2 and dry ice in University's laboratories	CO_2 and dry ice are used in University's laboratories.
Greenhouse gases emissions from INDIRECT ENERGY		
Production and transmissions of electricity	Building electricity production, transmission and consumption	Includes all activities of electricity production and transmissions to customers. In Québec, electricity is produced by hydropower in a proportion of 97 %. The other 3 % is from few thermal power plants used in high-demand periods.
OTHER INDIRECT ENERGY greenhouse gases emissions		
Fossil fuel production (heating oil, gasoline, diesel, natural gas, propane)	Fossil fuel production	Includes all activities of oil extraction, transport, refining and distribution. Since fossil fuels are used in every step of this process, total volume has to be considered.
Fossil fuel combustion (gasoline and diesel)	Home-to-work travel of employees	Includes the daily movement of employees from home to the University campus and vice versa. Emissions are from fossil fuel combustion in vehicles.
	Travel of employees while in duty	Includes the daily movement of employees in the frame of their work. Emissions are from fossil fuel combustion in vehicles.
	Home-to-University travel from students	Includes the daily movement of students from home to the University campus and vice versa. Emissions are from fossil fuel combustion in vehicles.
	Transportation of waste and recyclable, compostable and	Includes all activities involving waste transportation to landfills or to recycling and composting sites. Emissions are from fossil fuel combustion in vehicles.

	hazardous materials	
	Transportation of consumed paper	Includes all activities involving paper transportation from producer/distributor to Bishop's University. Emissions are from fossil fuel combustion in vehicles.
Waste landfilling	Waste Landfilling	Includes emissions from waste degradation in landfills.
Waste recycling	Waste recycling	Includes emissions involve in the recycling process. Emissions are principally from the use of motorised equipment (trucks) and from the energy used in recycling facilities.
Waste composting	Waste composting	Includes emissions involve in the composting process. Emissions are principally from the aerobic degradation of materials, the use of motorised equipment (trucks) and from the energy used in composting facilities.
Consumed paper production	Consumed paper production	Includes activities involving the production of paper used at Bishop's University.
Drinking water production	Drinking water consumption	Includes activities to retrieve, treat and distribute drinking water. Emissions are principally from the energy consumption of the process.
Wastewater treatment	Wastewater treatment	Includes the aerobic treatment of wastewater in City of Sherbrooke facilities. Emissions are from the nitrification and denitrification processes.

3 METHODOLOGY

The followed methodology used to quantify the GHG inventory is in accordance with the ISO 14 064-1 guidelines and specifications. All five fundamental principles are addressed adequately: relevance, completeness, consistency, accuracy, and transparency. The methodology can be summarized as follows:

1. Identification of GHG sources
2. Selection and collection of GHG activity data
3. Selection or development of GHG emission factors
4. Selection of quantification methodologies
5. Calculation of GHG emissions

3.1 Identification of GHG sources

The potential GHG emissions sources are:

- **Fixed combustion:** combustion of fossil fuels in fixed installations such as central heating boilers, turbines, radiators, motors, and flares.
- **Mobile combustion**: combustion of fossil fuels in motorised equipment such as cars, trucks, bus, trains, planes, and ships.

- **Emissions from physical or chemical processes:** emissions resulting from physical or chemical processes such as CO_2 emissions from acetylene combustion and consumed dry iced.
- **Fugitive emissions:** intentional or non-intentional (leaks) discharges such as GHG emissions from wastewater treatment and refrigerants.

3.2 Selection and collection of GHG activity data

Selection and data collection were based on primary and secondary information sources. Primary sources collected were from one of two distinctive methods:

1. Direct interviews with stakeholders
2. Official documentation, such as bills and invoices

Secondary information sources were obtained through Bishop's University website and other public available information.

3.3 Selection or development of GHG emission factors

In order to quantify the GHG emissions from the multiple sources included in the operational boundaries of this inventory, emission factors were selected.

When non-publicly available, emission factors were elaborated from indirect data given by reliable and credible references. This is the case for the following GHG emission factors:

1. Natural gas production (complete cycle, except finale use)
2. Heating oil production (complete cycle, except finale use)
3. Diesel production (complete cycle, except finale use)
4. Gasoline production (complete cycle, except finale use)
5. Propane production (complete cycle, except finale use)
6. Wastewater treatment

3.3.1 Fossil fuels production

Fossil fuels production GHG emission factors were derived from indirect data retrieved in the *GHGenius*[2] model. Energy product conversion factors as well as CO_2e emissions per unit of energy delivered to end users, by step and primary resource, were obtained from this software. Considered steps are:

[2] **Natural Resources Canada. 2013.** *GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. Québec: GWP=0.*

- Production, storage and distribution of fossil fuels
- Gathering, treatment and transport of primary resources
- Change in land uses and agricultural methods
- Chemical fertilizers production
- Gas leak and gas flaring
- Natural gas treatment for CO_2 and H_2S removal
- Emissions displaced

Table 3-1 presents data variables applied in quantification. An example of calculation for the GHG emission factor of natural gas follows.

TABLE 3-1: DATA VARIABLES APPLIED FOR THE DEVELOPMENT OF GHG EMISSION FACTORS – FOSSIL FUELS PRODUCTION

Fossil Fuels	CO_2E Emissions per Energy Unit	Energy Product Conversion Factors	Emission Factors
Natural gas	0.01064 kg/MJ	37.85 MJ/m³	0,40 kgCO₂éq/m³
Heating oil	0.01323 kg/MJ	38.65 MJ/L	0,51 kgCO₂éq/L
Propane	0.01294 kg/MJ	25.47 MJ/L	0,33 kgCO₂éq/L
Diesel	0.02048 kg/MJ	38.65 MJ/L	0,79 kgCO₂éq/L
Gasoline	0.02080 kg/MJ	34,69 MJ/L	0,72 kgCO₂éq/L

$$\frac{0{,}01064\ gCO_2e}{MJ} \times \frac{37{,}85\ MJ}{m^3\ NG} = \mathbf{0{,}40\ kgCO_2e/m^3\ NG}$$

3.3.2 Wastewater treatment

N_2O emissions associated with wastewater treatment were calculated according to the annual protein consumption rate of Bishop's University community. This data can be found in the Canadian GHG inventory report, published annually by Environment Canada[3], and was derived from annual alimentation statistics. For this report, a consumption of 69.85 kg per person per day was assumed.

The methodology used to define N_2O emissions factor was the Environment Canada's method applied in the National Inventory Report[4]. This quantification method, based on the International Panel for Climate Change (IPCC) model, includes the estimation on the availability of N_2O in function of waste material quantity of 0.01 kg N_2O-N/kg N.

[3] **Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064 (TableA3-51)
[4] **Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064 (Section A.3.5.3)

Furthermore, a proportion of 16 % of nitrogen in proteins was considered. Thus, the emission factor of N2O was estimated at 0.0641 kg N_2O/person.

$$\frac{69.85\ g\ protein}{person \cdot day} \times \frac{1\ ton}{1\ 000\ kg} \times \frac{365\ jours}{année} \times \frac{0.01\ \mathrm{kg\ N_2O - N}}{\mathrm{kg\ N}} \times \frac{0.16\ \mathrm{kg\ N}}{kg\ protein} \times \frac{44\ kg\ N_2O}{28\ kg\ \mathrm{N_2O - N}} = \frac{\mathbf{0{,}0641\ kg\ N_2O}}{\mathbf{person}}$$

Since wastewater facilities used by Bishop's University are based on an aerobic treatment of input, no CH_4 emissions are emitted from this activity.

3.3.3 Summary of chosen emission factors

Global emission factors, in CO_2e, are presented in table 3-2 with the associated reference. The same emission factors, divided into each greenhouse gas (CO_2, CH_4, N_2O and HFC), can be found in annex III.

TABLE 3-2: EMISSION FACTORS AND GLOBAL WARMING POTENTIAL USED FOR QUANTIFICATION

Component	Global Warming Potential (GWP)	Uncertainty	Reference
CO_2 emissions	1 $kgCO_2e/kgCO_2$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 1, table 1-1): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
CH_4 emissions	21 $kgCO_2e/kgCH_4$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 1, table 1-1): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
N_2O	310 $kgCO_2e/kgN_2O$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 1, table 1-1): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

Component	Emission Factors or GWP	Uncertainty	Reference
DIRECT greenhouse gases emissions			
Fossil fuel consumption by fixed combustion equipment (buildings)			
Natural gas combustion	1.89 $kgCO_2e/m^3$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2-A8): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Heating oil combustion	2.74 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2-A8-4): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion for fixed equipment (emergency generators)	2.79 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2-A8-4): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Propane combustion (residential)	1.54 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2-A8-4): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Fossil fuel consumption of mobile equipment			
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	2.30 $kgCO_2$éq/L	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Gasoline combustion – Light-duty trucks (tier 2; 2004-2013)	2.30 $kgCO_2$éq/L	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Gasoline combustion – Off-road vehicles	2.36 $kgCO_2$éq/L	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion – Light-duty vehicles (Advanced control)	2.73 $kgCO_2$éq/L	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion – Heavy-duty vehicles (Advanced control)	2.71 $kgCO_2$éq/L	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

Diesel combustion – Light-duty trucks (Advanced control)	2.73 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion – Off-road vehicles	3.01 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Propane combustion – Off-road vehicles (Zamboni)	1.53 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Refrigerant from air conditioning systems in buildings and vehicles			
Consumption of R404a	3,26 $kgCO_2e/kg$	Low	1. United Nations Environment Programme (UNEP), 2011. 2010 Report of the refrigeration, air conditioning and heat pumps technical options committee. (Table 2-1), ISBN: 978-9966-20-002-0. 2. Canadian Standard Association, 2006. ISO 14064-1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removal
Consumption of R409a	1.29 $kgCO_2e/kg$	Low	
Consumption of R410a	1.73 $kgCO_2e/kg$	Low	
Consumption of R414b	1.20 $kgCO_2e/kg$	Low	
Consumption of R134a	1.30 $kgCO_2e/kg$	Low	

Greenhouse gases emissions from INDIRECT ENERGY

Production and transmissions of electricity	0.002 $kgCO_2e/kWh$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 3, Table A13-6): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

OTHER INDIRECT ENERGY greenhouse gases emissions

Home-to-University travel of students and employees and travel of employees in duty			
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	2.30 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion – Heavy-duty vehicles (Advanced control)	2.71 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Landfilling, recycling and composting of waste			
Composting of organic material	177 $kgCO_2e/t$	Medium	IPCC, 2006. Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 4: Biological treatment of solid waste.
Plastic recycling process (n°1 à n°5)[5]	0.58 $kgCO_2e/kg$	Medium	ICF Consulting. 2005. Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update - Draft Report (Exhibit ES-2)
Paper recycling process[6]	0.89 $kgCO_2e/kg$	Medium	
Plane carton recycling process	0.86 $kgCO_2e/kg$	Medium	
Metal recycling process[7]	0.94 $kgCO_2e/kg$	Medium	
Glass recycling process	0.30 $kgCO_2éq/kg$	Medium	
Fossil fuels production			
Natural gas production (complete cycle, except finale use)	0.40 $kgCO_2eq/m^3$	Low	Natural Resources Canada. 2013. GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 ("Upstream results HHV", cell CS20)
Heating oil production (complete cycle, except finale use)	0.51 $kgCO_2eq/L$	Low	Natural Resources Canada. 2013. GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 ("Upstream results HHV", cell I20)
Propane production (complete	0.33 $kgCO_2e/L$	Low	Natural Resources Canada. 2013. GHGenius - A model

[5] Considered proportions: 33 % HDPE, 36 % PET and 31 % other plastics. Based on RECYC-QUÉBEC.
[6] Considered proportions: 38 % fine paper, 14 % newspapers and 48 % carton. Based on RECYC-QUÉBEC.
[7] Considered proportions: 88 % steel, 12 % aluminium Based on RECYC-QUÉBEC.

cycle, except finale use)			for lifecycle assessment of transportation fuels. Version 4.03. 2013 ("Upstream results HHV", cell M20)
Diesel production (complete cycle, except finale use)	0.79 $kgCO_2e/L$	Low	Natural Resources Canada. 2013. GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 ("Upstream results HHV", cell F20)
Gasoline production (complete cycle, except finale use)	0.72 $kgCO_2e/L$	Low	Natural Resources Canada. 2013. GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 ("Upstream results HHV", cell D20)
Transport of waste and recyclable, compostable and hazardous materials			
Diesel combustion – Heavy-duty vehicles (Advanced control)	2.71 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Consumed paper production and transport			
Paper production – 100% recycled 8"½ x 11"	4.01 $kgCO_2e$/pack	Medium	Ministry of Environment, 2012. 2012 B.C. Practices Methodology for Quantifying Greenhouse Gas Emissions - Including Guidance for Public Sector Organizations, Local Governments and Community Emissions.
Paper production – 50% recycled 8"½ x 11"	5.18 $kgCO_2e$/pack	Medium	
Paper production – 30% recycled 8"½ x 11"	5.65 $kgCO_2e$/pack	Medium	
Paper production – 30% recycled 8"½ x 14"	7.20 $kgCO_2e$/pack	Medium	
Paper production – 30% recycled 11" x 17"	11.33 $kgCO_2e$/pack	Medium	
Paper production – 10% recycled 8"½ x 11"	6.12 $kgCO_2e$/pack	Medium	
Paper production – 10% recycled 11" x 17"	12.27 $kgCO_2e$/pack	Medium	
Paper production – 0% recycled 8"½ x 11"	6.36 kgCO2e/pack	Medium	
Paper production – 0% recycled 8"½ x 14"	8.09 $kgCO_2e$/pack	Medium	
Paper production – 0% recycled 11" x 17"	12.74 $kgCO_2e$/pack	Medium	
Diesel combustion – Heavy-duty vehicles (Advanced control)	2.71 $kgCO_2e/L$	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Drinking water consumption			
Production of consumed drinking water[8]	0.02 $kgCO_2e/m^3$	High	Logé, H. 2006. Plan d'action corporatif « Pour préserver le climat », Ville de Montréal, Service des infrastructures, transport et environnement, p.27 (Tableau 4).
Wastewater treatment			
Wastewater treatment	19.87 $kgCO_2e$/pers-year	Low	Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

[8] Mean emissions factor derived from six drinking water treatment facilities in Montreal.

3.4 Selection of quantification methodologies

The majority of the quantification methodologies used in the GHG inventory are based on the multiplication of GHG activity data by an appropriated emission factor. Since the university does not measure GHG emissions directly from its sources and this inventory is not part of any specific program, this methodology is the most precise, coherent, and reproducible.

According to Kyoto Protocol, aimed greenhouse gases are CO_2, CH_4, N_2O, SF_6, PFCs and HFCs. Each of these specific gases possesses its own global warming potential (GWP). GWP is the capacity from a gas to trap heat into the atmosphere and it is expressed as a factor of CO_2. This way of characterise GHG gases helps to compare emissions by giving results in one unique unit, the CO_2 equivalent (CO_2e).Thus, global warming potential from CO_2 is 1 CO_2e while it is 21 CO_2e for CH_4 and 310 for N_2O. All GWP included in Kyoto Protocol can be found in annex II.

3.4.1 Direct GHG emissions

FOSSIL FUEL COMBUSTION BY FIXED AND MOBILE EQUIPMENT

Direct GHG emissions from fossil fuel combustion in fixed and mobile equipment are calculated by multiplying annual fossil fuel consumption for each equipment to its appropriate emission factor for CO_2, CH_4, and N_2O. Results are then transferred in CO_2e by using GWP factors.

Below is an example of GHG quantification for the consumption of natural gas for all University buildings.

$$CO_2\ annual\ emissions = 1{,}211{,}156\ m^3NG \times \frac{1{,}878\ kgCO_2}{m^3NG} = 2{,}274{,}551\ kgCO_2 = 2{,}274\ t\ CO_2$$

$$CH_4\ annual\ emissions = 1{,}211{,}156\ m^3NG * \frac{0{,}000037\ kgCH_4}{m^3NG} = 45\ kgCH_4 = 0{,}04\ t\ CH_4$$

$$N_2O\ annual\ emissions = 1{,}211{,}156\ m^3NG * \frac{0{,}000035\ kgN_2O}{m^3NG} = 42\ kgN_2O = 0{,}04\ ton\ N_2O$$

$$CO_2e\ annual\ emissions = 2{,}274\ t + (0{,}04 \times 21)\ t + (0{,}04 \times 310)\ t = \mathbf{2,288.63\ t\ CO_2e}$$

AIR CONDITIONING AND REFRIGERATION IN BUILDINGS

HFCs used in air conditioning (AC) and refrigeration systems are potential sources of GHG emissions. In fact, intentional and non-intentional gas leaks regularly occur in AC and refrigeration systems. To determine GHG emissions from this type of source, the Environment Canada methodology is followed[9]:

$$GHG\ annual\ emissions\ (kg) = \left[(Q_n * k) + (C * x * A) + (Q_d * y * (1 - z))\right]$$

Q_n: Quantity of added refrigerant to equipment (kg)

k: Initial emissions (%)

C: Total capacity of equipment (kg)

x: Operational emissions (%)

A: Number of utility years

Q_d: Non-used equipment capacity (kg)

y: Residual charge in equipment (%)

z: Recovery efficiency at disposal (%)

x, y, z and k values for residential and commercial use can be found in IPCC publications for residential and commercial use[10]. Since Bishop's University did not add or eliminate any of AC and refrigeration systems in 2012, Q_n and Q_d equal 0 in relative quantifications. Calculated GHG annual emissions are multiplied to specific GWPs. In the case of Bishop's University, four GWPs are used: 3.26 kgCO_2e per kg of R404a, 1.29 kgCO_2e per kg of R409a, 1.73 kgCO_2e per kg of R410a and 1.20 kgCO_2e per kg of R414b.

Most of equipment charges and capacities were known. Estimations to evaluate unknown charges and capacities as well as the value of x and A were based on table 3-3.

Not all refrigerant used by Bishop's University are included in the Kyoto Protocol and thus, are not considered in ISO 14064-1. Those powerful GHG are already addressed in the Montreal Protocol[11] as they qualify as ozone-depleting substances (ODS)

[9] Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

[10] Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3 : Industrial Processes and Product Use.*

[11] The Montreal Protocol, adopted on September 22nd, 1985, is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion.

TABLE 3-3: CHARGE AND LIFETIME ESTIMATIONS OF EMISSION FACTORS FOR AIR CONDITIONING AND REFRIGERATION SYSTEMS IN BUILDINGS[12]

	EQUATION FACTORS				
	Charge (kg)	Initial emissions **k** (% of initial charge)	Operational emissions **x** (% of initial charge/year)	Residual charge **y** (% of initial charge)	Recovery efficiency **z** (% of residual)
Residential air conditioning	0.05-0.5	1 %	0.5%	80 %	70 %
Independant commercial applications	0.2-6	3 %	15 %	80 %	70 %
Large and medium size commercial refrigeration	50-2,000	3 %	35 %	100 %	70 %
Industrial refrigeration (food production included)	10-10,000	3 %	25 %	100 %	90 %
Coolers	10-2,000	1 %	15 %	100 %	95 %
Residential and commercial air conditioning systems with heat pumps	0.5-100	1 %	10 %	80 %	80 %

An example of GHG emissions quantification from refrigerants in buildings can be found below. It involves the Library air conditioning system working on R410a.

$$\begin{aligned} Annual\ emissions\ (kg) = {} & [0 + (2.72kg \times 10\ \% \times 1\ year) + 0] \div 1000 \\ = {} & 0.000272\ kgR410a \end{aligned}$$

$$0.000272\ kgR410a \times \frac{1{,}730\ kgCO_2e}{kgR410a} \times \frac{1\ tCO_2e}{1000\ kgCO_2e} = \mathbf{0.47\ tCO_2e}$$

AIR CONDITIONING AND REFRIGERATION IN MOBILE EQUIPMENT

HFCs used in air conditioning (AC) systems of mobile motorised equipment are also potential sources of GHG emissions. Leaks and discharges into the atmosphere of HFCs used in mobile equipment can be estimated from the following equation[13]:

[12] Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3 : Industrial Processes and Product Use.* “y” and “z” represent “($n_{rec,d}$)” and “(p)”.
[13] Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3 : Industrial Processes and Product Use.*

$$GHG\ annual\ emissions\ (kg) = \left[(C * x * A) + (Q_d * y * (1 - z))\right]$$

C : Total equipment capacity (kg)
x : Operational emissions (%)
A : Number of utility years
Q_d : Non-used equipment capacity (kg)
y : Residual charge in equipment (%)
z : recovery efficiency at disposal (%)

Table 3-4 gives proposed values for x, y and z according to IPCC publications. In the instance that total equipment capacity is unknown, highest estimated value is used (1.5kg).

TABLE 3-4: CHARGE AND LIFETIME ESTIMATIONS OF EMISSION FACTORS FOR AIR CONDITIONING SYSTEMS IN MOBILE EQUIPMENT

Total equipment capacity (C)	Operational emissions (x)	Residual charge (y)	Recovery efficiency (z)
0.5 – 1.5 kg	20 %	50 %	50 %

An example of GHG emissions quantification from refrigerants in mobile equipment can be found below. It calculates the GHG emissions from the 2009 Ford Escape used by the Security department[14].

$$CO_2e\ annual\ emissions = \left[(1{,}5\ kg \times 10\ \% \times 1\ year) + \left(0\ kg \times 50\ \% \times (1 - 50\ \%)\right)\right] \times \frac{1\ t}{1\ 000\ kg} \times \frac{1\ 300\ kg\ CO_2e}{kg} = \mathbf{0{,}195\ t\ CO_2e}$$

ACETYLENE COMBUSTION (SOLDERING)

For the quantification of GHG emissions derived from the use of acetylene in smoldering activities, methodology was based on mass balance and stoichiometry.

Thus, with known acetylene consumption for 2012 of 3.13 m^3, the use of the ideal gas law and the acetylene combustion equation, it was possible to evaluate the amount of GHG emissions caused by this activity.

Ideal gaz law :

$$P \cdot V = n \cdot R \cdot T$$

[14] Assume the use of R134a in air conditioning system.

Where,

P = 15 bar[15]
V = Quantity of used acetylene (L)
n = Number of moles
R = 0.083 L·bar/mol·K
T = 288 K (15 °C)

Acetylene combustion equation :

$$2\,C_2H_2 + 5\,O_2 \rightarrow 4\,CO_2 + 2\,H_2O$$

From n value (ideal gas law) and with known molar mass of acetylene (26,04 g/mol), CO_2e emissions could be estimated as follow:

$$n \times stoechiometry \times MM_{acetylene} = n \times \frac{4}{2} \times 26{,}04$$

$$n = \frac{15\ bar \times 3{,}130\ L}{0{,}083\ \ L \cdot bar/mol \cdot K \times 288\ K} = 1{,}959.8\ mol$$

$$1{,}959.8\ mol \times \frac{4}{2} \times 26{,}04\ \ g/mol = 102.1\ kgCO_2 = \mathbf{0.1\ t\ CO_2e}$$

3.4.2 Indirect energy GHG emissions

BUILDING ELECTRICITY PRODUCTION AND TRANSMISSION

GHG emissions from electricity consumption were obtained by multiplying the annual total of electricity used in 2012 (kWh) by the Quebec's electricity emission factor. An example of quantification can be found below and included for all building electricity consumption:

$$CO_2 emissions = \ 10{,}422{,}000\ kWh \times \frac{0{,}002\ kgCO_2}{kWh} = \ 17{,}260\ kgCO_2 = 17.26\ t\ CO_2$$

$$CH_4 annual\ emissions = \ 10{,}422{,}000\ kWh \times \frac{0{,}0000003\ kgCH_4}{kWh} = \ 2.1\ kgCH_4 = 0{,}002\ t\ CH_4$$

$$N_2O\ annual\ emissions = \ 10{,}422{,}000\ kWh \times \frac{0{,}0000001\ kgN_2O}{kWh} = \ 1.05\ kgN_2O = 0{,}001\ t\ N_2O$$

$$CO_2e\ annual\ emissions = \ 17.26\ t + (0{,}002 \times 21)\ t + (0{,}001 \times 310)\ t = \mathbf{17.63\ t\ CO_2e}$$

[15] Organisme professionnel de prévention du bâtiment et des travaux publics (OPPBTP), France.

3.4.3 Other indirect GHG emissions

FOSSIL FUELS PRODUCTION

Quantification of other indirect GHG emissions from the production of fossil fuels (heating oil, natural gas, propane, gasoline and diesel) is obtained by the multiplication of the annual consumption of each fuel type (L or m^3) by its corresponding GHG emission factor. An example of this methodology can be found below.

$$CO_2e\ annual\ emissions = \ 1{,}211{,}156\, m^3\ of\ natural\ gas\ (NG) \times \frac{0{,}40\ kgCO_2e}{m^3 NG}$$
$$= 487{,}945\ kgCO_2e = \ \mathbf{487.9\ t\ CO_2e}$$

WASTE LANDFILLING

Landfill Gas Emissions Model (LandGEM) available at the Environmental Protection Agency (EPA) was used to estimate GHG emissions derived by landfilling activities. This model helps to determine CO_2 and CH_4 emissions on a yearly basis and required historical assessment of total landfilled waste quantity per year for the past 50 years.

Since 2010, waste materials are sent to the Saint-Étienne-des-Grès Landfill facility which possesses a landfill gas collection system with 62 % efficiency[16]. In 2009, waste materials were transported to Saint-Nicéphore Landfill facility which also has a landfill gas collection system with 90 % efficiency[17]. Before 2009, waste materials were eliminated at the Sherbrooke Landfill facility with a 70 % efficiency[18] landfill gas collection system.

LandGEM uses the following equation to estimate the waste material degradation rate:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0,1}^{1} kL_o \left(\frac{M_i}{10}\right) e^{-kt_{i,j}}$$

Where,

Q_{CH_4} : annual methane generation in the year of the calculation (m^3/year)

i : 1 year time increment

n : (year of the calculation) – (initial year of waste acceptance)

j : 0.1 year time increment

k : methane generation rate ($year^{-1}$)

L_o : potential methane generation rate (m^3/t)

M_i : mass of waste accepted in the i^{th} year (t)

$t_{i,j}$: age of the j^{th} section of waste mass M, accepted in the i^{th} year (decimal years, e.g., 3.2 years)

[16] Julie Bourassa, Saint-Étienne-des-Grès Landfill facility.
[17] Simon Mercier, Waste Management.
[18] Jonathan Drouin, Ville de Sherbrooke.

LandGEM parameters are time sensitive. Thus, L_o and k values change with the time-period with which they are associated but also regarding the waste composition. From the Canadian Inventory Report[19], L_o and k values for the Province of Quebec can be expressed as:

TABLE 3-5: L_O AND K VALUES FOR THE PROVINCE OF QUEBEC

Landfill facility	L_o (m^3/t)			k ($year^{-1}$)		
	1962-1975	1976-1989	1990-2012	1962-1975	1976-1989	1990-2012
Saint-Étienne des Grès	-	-	115.57	-	-	0.059
Saint-Nicéphore	-	-	115.67	-	-	0.059
Sherbrooke	228.45	188.97	115.67	0.053	0.057	0.059

For the evaluation of 2012 Bishop's University GHG emissions from waste disposal, total of waste material sent to landfill facilities(M_i) has been used in LandGEM. For periods where total was unknown, estimations were made by factoring the university annual community size (annual total of employees and students).

Five LandGEM simulations were completed for five different time-periods (1962-1975, 1976-1989, 1990-2008, 2009, 2010-2012). GHG emission estimations where extracted from each simulation for the year 2012. Landfill gas collection systems were then considered by multiplying those results to the appropriate systems efficiency (62 % for Sherbrooke, 90 % for Saint-Nicéphore and 70 % for Saint-Étienne-des-Grès).

RECYCLING AND COMPOSTING OF WASTE MATERIALS

Emissions from recycling and composting processes were calculated by multiplying the total amount of recycled or composted materials to the corresponding emission factor. An example of the methodology used for the composted materials is found below.

$$CO_2e\ annual\ emissions = 85\ t\ of\ waste \times \frac{177\ kgCO_2e}{tons\ of\ waste} = 15.045\ kgCO_2e$$
$$= \mathbf{15.05\ t\ CO_2e}$$

Note: Since recycling emission factors are sensitive to the type of recycled material and that only a total quantity of the recycled material was known for 2012, average known data to estimate each type of material proportion (glass, paper, metal, etc.) was retrieved from RECYC-QUÉBEC publications[20].

[19] Environment Canada. 2013. *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa: Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

[20] RECYC-QUÉBEC, 2009. Portrait de la gestion des matières résiduelles dans le sous-secteur institutionnel au Québec – Rapport synthèse 2004-2009.

FOSSIL FUEL CONSUMPTION BY EMPLOYEES AND STUDENTS

GHG emissions derived from home-to-university travel by both employees and students were calculated by using the number of part-time and full-time employees and students. Proportions of those travelling distances were estimated according to table 3-6[21].

TABLE 3-6: AVERAGE ESTIMATED PROPORTION OF TRANSPORTATION TYPE AND TRAVELED DISTANCE PER DAY

	Proportion (%)	Average estimated distance (two-way, km)
Employees (home-to-campus)		
Full-time faculty and staff travelling by bus	10	20
Full-time faculty and staff travelling by car	80	40
Full-time faculty and staff travelling by walk	10	-
Part-time faculty and staff travelling by car	100	40
Students[22]		
Students travelling by bus (<5km)	8	10
Students travelling by walk (<5km)	64	10
Students travelling by car (<5km)	8	10
Students travelling by car (>5km)	20	35

As students and employees do not have the same attendance schedule on campus, an estimation of total annual days of work and class was obtained from the academic calendar and from the university's human resources department. Full-time faculty and staff attendance was estimated as follows:

$$48\ working\ weeks \times 5\ days - 11\ statutory\ holidays = 229\ days$$

For past-time faculty and staff, the estimated attendance time was calculated as follows:

$$34\ working\ weeks \times 2\ days - 8\ statutory\ holidays^{23} = 60\ days$$

According to the academic calendar, student attendance on campus is about 253 days per year.

Total annual distance was calculated using the following equation (example of full-time faculty and staff travelling by car):

$$275\ employees * 80\% * 40km * 229\ days = 2{,}015{,}200\ km$$

From this calculated result, total annual fuel consumption is derived and GHG emissions are calculated by multiplying this consumption to the appropriate emission factor, as demonstrated below.

[21] Estimation by Michel Caron, Bishop's University, Buildings and Ground Services Director.
[22] Excludes the 700 students living on campus. All distance and transportation types used by students were obtained following direct consultations.
[23] Time-period attendance is from September through April.

TABLE 3-7: MEAN FUEL CONSUMPTION PER VEHICULE TYPE

Vehicle types	L/100km
Consumption rate for light-duty gasoline vehicles (tier 2; 2004-2013)[24]	8.8
Consumption rate for heavy-duty diesel vehicles (bus)[25]	53.31
Walk	0

Some assumptions were made to estimate GHG emissions with the given available data:

i. All students and employees' cars are fueled by gasoline and can be characterized as light-duty vehicles, tier 2, 2004-2012.

ii. Only total seating places in bus were occupied by travel (41 seats)[26].

For total gasoline consumption by students travel home-to-campus (cars):

$$CO_2\ annual\ emissions = 3{,}285{,}711\ km * \frac{8.8\ L}{100\ km} * \frac{2.29\ kgCO_2}{L} = 661{,}847.34\ kgCO_2$$

$$= 661.85\ t\ CO_2$$

$$CH_4\ annual\ emissions = 3{,}285{,}711\ km * \frac{8.8\ L}{100\ km} * \frac{0.00014\ kgCH_4}{L} = 40.45\ kgCH_4$$

$$= 0.04\ t\ CH_4$$

$$N_2O\ annual\ emissions = 3{,}285{,}711\ km * \frac{8.8\ L}{100\ km} * \frac{0.00002\ kgN_2O}{L} = 6.36\ kgN_2O$$

$$= 0.0006\ t\ N_2O$$

$$CO_2e\ annual\ emissions = 661.85\ t + (0.04 * 21)\ t + (0.0006 * 310)\ t$$
$$= \mathbf{664.67\ t\ CO_2e}$$

For total diesel consumption by students travel home-to-campus (bus):

$$CO_2\ annual\ emissions = 177{,}606\ km * \frac{51.31\ L}{100\ km} * \frac{2.66\ kgCO_2}{L} = 863{,}417.27\ kgCO_2$$

$$= 863.42\ t\ CO_2$$

[24] Derived from: Natural Resources Canada, 2010. Comprehensive Energy Use Database Table, Table 21 : Car Explanatory Variables.
[25] Transport Canada, 2011. Fuel Efficiency by Vehicule Class, Urban Transportation Emission Calculator.
[26] Based on : Novabus, 2010. Caractéristiques techniques.

$$CH_4 \; annual \; emissions = 177{,}606 \; km * \frac{51.31 \; L}{100 \; km} * \frac{0.00014 \; kgCH_4}{L} = \; 35.67 \; kgCH_4$$
$$= 0.04 \; t \; CH_4$$

$$N_2O \; annual \; emissions = 177{,}606 \; km * \frac{51.31 \; L}{100 \; km} * \frac{0.00002 \; kgN_2O}{L} = \; 48.96 \; kgN_2O$$
$$= 0.05 \; t \; N_2O$$

$$CO_2e \; annual \; emissions = \; 863.42 \; t + (0.04 * 21) \; t + (0.05 * 310) \; t = \mathbf{879.34 \; t \; CO_2e}$$

Note: Quantification of GHG emissions from fossil fuel consumption by employees and students were done using the assumption presented above since more accurate data were not available at the time of quantification. Bishop's University plans to implement, in the beginning of 2014, an information system to gather more accurate data based on studies and survey of the students and employees transportation means. Therefore, for the 2014 GHG inventory, the methodologies for calculating those emissions will be modifying to enable the uses of the more accurate data.

FOSSIL FUEL CONSUMPTION FOR BUSINESS TRAVEL OF EMPLOYEES

GHG emissions from fossil fuel consumption for business travel were only calculated for travel done by car. GHG emissions from business travel by bus, train and plane were not quantified since data, such as distance traveled by those means of transportation, were not available at the time of quantification. However, Bishop's University plans on modifying the expense system, in the beginning of 2014, to capture accurate data needed for quantifying GHG emissions for all types of business travel.

For business travel done by car, Bishop's University[27] provided the amount of total expenses for business travel and proportions of this amount which is allocated to fuel purchase for car travel as presented in the following table:

TABLE 3-8: PROPORTION OF BUSINESS TRAVEL BY CAR

	$	%
Total annual expenses	970,000	
Proportion of expenses allocated to transport	291,000	30%
Proportion of transport expenses allocated to car travel	218,250	75%
Proportion of car's travel expenses allocated to fuel purchase	72,023	33%

Assuming an average cost of 1.42 $/L[28] of gasoline, business travel by car consumed in 2012 50,720 L of gasoline.

[27] Data provided by Bishop's University accounting department and by Michel Caron, Bishop's University, Buildings and Ground Services Director.

The assumption was made to estimate GHG emissions that all cars are fueled by gasoline and can be characterized as light-duty vehicles, tier 2, 2004-2012.

For total fuel consumption from business travel by car, GHG emissions are calculated hereafter:

$$CO_2\ annual\ emissions = 50{,}720\ L * \frac{2.29\ kgCO_2}{L} = 116{,}100\ kgCO_2 = 116.1\ t\ CO_2$$

$$CH_4\ annual\ emissions = 50{,}720\ L * \frac{0.00014\ kgCH_4}{L} = 7\ kgCH_4 = 0.007\ t\ CH_4$$

$$N_2O\ annual\ emissions = 50{,}720\ L * \frac{0.00002\ kgN_2O}{L} = 1\ kgN_2O = 0.001\ t\ N_2O$$

$$CO_2e\ annual\ emissions = 116.1\ t + (0.007 * 21)\ t + (0.001 * 310)\ t = \mathbf{116.59\ t\ CO_2e}$$

FOSSIL FUEL CONSUMPTION BY WASTE MATERIAL TRANSPORTATION

Total diesel consumption for transportation of waste material from the university to suitable elimination facilities was estimated by using an average weight capacity for heavy-duty vehicles[29], as well as the distance between the university and those facilities (table 3-8). The specific fuel consumption of 33,4 L/100 km for this type of heavy-duty trucks was retrieved from the Office of Energy Efficiency website[30]:

TABLE 3-9: DISTANCE OF WASTE FACILITIES FROM BISHOP'S UNIVERSITY

Facility type	City	Distance (two-way, km)
Landfill	Saint-Étienne-des-Grès	350
Recycling	Sherbrooke	25
Composting	Bury	70
Hazardous waste	Burlington, Ontario	1,500

For the transport of compostable waste to the Valoris facility in Bury, Quebec:

$$70\ km * \frac{0.334\ l}{km} * \frac{85\ t\ of\ material}{20\ t\ of\ capacity} = 99\ L\ of\ diesel$$

[28] Data provided by Bishop's University accounting department and by Michel Caron, Bishop's University, Buildings and Ground Services Director.
[29] Maximum accepted charge for garbage collection trucks. Government of Quebec, 2011, *Règlement sur les normes de charges et de dimensions applicables aux véhicules routiers et aux ensembles de véhicules routiers.*
[30] Natural Resources Canada, 2009. 2009 Canadian Vehicla Survey Summary Report, Office of Energy Efficiency.

$$CO_2\ annual\ emissions = 99\ L\ diesel \times \frac{2.66\ kg}{L\ diesel} = 264.6\ kg = \ 0.26\ t$$

$$CH_4 annual\ emissions = 99\ L\ diesel \times \frac{0.00011\ kg}{L\ diesel} = 0.011\ kg = \ 0.00001\ t$$

$$N_2O\ annual\ emissions = 99\ L\ diesel \times \frac{0.000151\ kg}{L\ diesel} = 0.015\ kg = \ 0.00002\ t$$

$$CO_2e\ annual\ emissions = \ 0.26\ t + (0{,}00001 \times 21)\ t + (0{,}00002 \times 310)\ t$$
$$= \mathbf{0{,}27\ t\ CO_2e}$$

FOSSIL FUEL CONSUMPTION FOR PAPER TRANSPORTATION

Bishop's University acquires its office paper from four different producers (table 3-9). To estimate total fuel consumption required to transport the office paper, maximum weight capacity of trucks were used (20 tonnes), as well as the proportion of purchases from each producers. To begin, total weight of all acquired paper in 2012 was estimated by using the quantity of sheets purchased by the university as demonstrated in this example (Cascades Rolland ReproPlus 50):

$$1{,}400{,}000\ sheets * (8.5\ in * 11\ in) * \frac{0.00065\ m^2}{in^2} * \frac{0.075\ kg}{m^2} = 6{,}334\ kg$$

Facility	City	Distance (two-way, km)	Proportion of purchases (%)
Cascades	Kingsey Falls, Qc	155	41.5
Domtar	Windsor, Qc	60	58.1
Sterling paper	USA	300	0.1
U-Digital paper	Ville Saint-Laurent, Qc	350	0.3

$$\frac{6.334\ t}{20\ t} * \frac{6.334\ t}{15.85\ t} * 155\ km * \frac{0.334\ L\ diesel}{km} = 17\ L\ diesel$$

$$CO_2\ annual\ emissions = 17\ L\ diesel \times \frac{2.66\ kg}{L\ diesel} = 45\ kg = \ 0.045\ t$$

$$CH_4 annual\ emissions = 17\ L\ diesel \times \frac{0.00011\ kg}{L\ diesel} = 0.0019\ kg = \ 0.000002\ t$$

$$N_2O\ annual\ emissions = 17\ L\ diesel \times \frac{0.000151\ kg}{L\ diesel} = 0.0026\ kg = \ 0.000003\ t$$

$$CO_2e\ annual\ emissions = \ 0.045\ t + (0{,}000002 \times 21)\ t + (0{,}000003 \times 310)\ t$$
$$= \mathbf{0{,}046\ t\ CO_2e}$$

PRODUCTION OF OFFICE PAPER

All purchased paper types present different recycled paper content. Thus, GHG emissions were calculated by multiplying the estimated quantity of paper packs for each type (see previous section) to its corresponding emission factor. Here is an example of GHG emission quantification for the production of the Cascades Rolland ReproPlus with 50 % of recycled content:

$$1{,}400{,}000\ sheets \div \frac{500\ sheets}{pack} = 2{,}800\ paper\ packs$$

$$CO_2e\ annual\ emissions = 2{,}800\ packs * \frac{5.18\ kgCO_2e}{pack} = 14{,}515\ kg\ CO_2e$$
$$= \mathbf{14.52\ t\ CO_2e}$$

DRINKING WATER PRODUCTION

To quantify the GHG emissions from the production of consumed drinking water on campus, the total amount of consumed drinking water had to be multiplied by the emission factor evaluated from the drinking water treatment facilities, located in Sherbrooke. Since Bishop's University does not monitor water consumption on campus, this data had to be estimated by using the annual average drinking water consumption per person in Quebec[31]. An example of this quantification is presented below for full-time faculty and staff.

	Hours/day	Proportion of the day (%)
Estimated mean time-period spent on campus by student, faculty and staff	10	42
Estimated mean time-period on campus for resident students	24	100

$$\frac{229\ days}{year} * 275\ employees * \frac{400\ \mathrm{L}}{pers \cdot day} * 42\ \% = 10{,}496\ m^3/year$$

$$CO_2e\ annual\ emissions = \frac{10{,}496\ m^3}{year} * \frac{0.02\ kgCO_2e}{m^3} = 174.9\ kgCO_2e = \mathbf{0.17\ t\ CO_2e}$$

WASTEWATER TREATMENT

GHG emissions quantification for wastewater treatment considered two aspects:

1) emissions from the use of energy at treatment facilities;
2) emissions from the aerobic biological degradation of organic material.

[31] MDDEFP, 2013. La gestion de l'eau au Québec, http://www.mddefp.gouv.qc.ca/eau/consultation/themes3.htm.

The energy consumption for Bishop's University at Sherbrooke wastewater treatment facilities was estimated using the annual amount of treated wastewater, the total energy used at the facilities, and the annual drinking water consumption on campus[32]:

$$\frac{602{,}719\ kWh}{year} * \frac{1{,}314{,}000\ m^3}{year} = 0.46\ kWh/m^3$$

$$\frac{0.46\ kWh}{m^3} * \frac{158{,}747\ m^3}{year} = 72{,}816\ kWh/year$$

GHG emissions were then calculated by multiplying total annual wastewater by the appropriate emission factor:

$$CO_2\ annual\ emissions = \frac{72{,}816\ kWh}{year} * \frac{0.00164\ kgCO_2}{kWh} = 119.4\ kgCO_2$$
$$= \mathbf{0.119\ t\ CO_2}$$

$$CH_4\ annual\ emissions = \frac{72{,}816\ kWh}{year} * \frac{0.0000002\ kgCH_4}{kWh} = 0.0146\ kgCH_4$$
$$= \mathbf{0.00001\ t\ CH_4}$$

$$N_2O\ annual\ emissions = \frac{72{,}816\ kWh}{year} * \frac{0.0000001\ kgN_2O}{kWh} = 0.00728\ kgN_2O$$
$$= \mathbf{0.00001\ t\ N_2O}$$

$$CO_2e\ annual\ emissions = 0.119\ t + (0{,}00001 \times 21)\ t + (0{,}00001 \times 310)\ t$$
$$= \mathbf{0{,}122\ t\ CO_2e}$$

The GHG emissions from the aerobic biological degradation of organic material for Bishop's University were estimated as follows[33] (example of full-time faculty and staff):

$$N_2O\ annual\ emissions = 275\ employees * \frac{0.06\ kgN_2O}{pers.\cdot year} = 17.63\ kgN_2O$$
$$= \mathbf{0.018\ t\ N_2O}$$

$$CO_2e\ annual\ emissions = 0 + (0 \times 21)\ t + (0{,}018 \times 310)\ t = \mathbf{5.46\ t\ CO_2e}$$

[32] For a conservative estimation, it is assumed that the total amount of consumed drinking water is sent to wastewater treatment after use.

[33] According to Environment Canada (2013), CO_2 and CH_4 emissions from aerobic biological degradation are considered non significative.

4 GHG QUANTIFICATION RESULTS

All calculations were executed according to the Standard ISO 14064 – Part 1 and to the selected methodology explained in section 3. Section 4 presents the complete results from quantification.

4.1 Quantification of direct GHG emissions

4.1.1 Buildings

TABLE 4-1: DIRECT GHG EMISSIONS FOR BUILDINGS

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total direct emissions
Fossil fuel combustion									
Heating oil	23,648.10	liters	64.44	0.001	0.001	-	64.68	2.72 %	2.65 %
Natural gas	1,211,156.00	m^3	2,274.55	0.04	0.04	-	2,288.63	96.16 %	93,65 %
Propane	312.18	liters	0.47	0.00001	0.00003	-	0.48	0.02 %	0.02 %
Diesel	9,376.00	liters	24.97	0.001	0.004	-	26.16	1.10 %	1.07 %
SUB-TOTAL			***2,364.43***	***0.05***	***0.05***	-	***2,379.95***	***100 %***	***97.39 %***
Refrigerant leaks in air conditioning systems									
R404a	14	systems	-	-	-	0.005	17.67	27.74 %	0.72 %
R409a	1	system	-	-	-	0.001	1.53	2.40 %	0.06 %
R410a	11	systems	-	-	-	0.002	3.85	6.05 %	0.16 %
R414b	1	system	-	-	-	0.001	1.06	1.66 %	0.04 %
R134a	26	systems	-	-	-	0.030	39.58	62.15 %	1.62 %
SUB-TOTAL			-	-	-	***0.039***	***63.69***	***100 %***	***2.61 %***
Leaks of gaseous CO_2 in University's laboratories									
Combustion of acetylene	3.13	m^3	-	-	-	-	0.1	76.92 %	0.004 %
Use of dry ice	30	lbs	-	-	-	-	0.011	8.46 %	0.00005 %
Use of gaseous CO_2	25	lbs	-	-	-	-	0.013	10,00 %	0.00005 %
SUB-TOTAL			-	-	-	-	***0.13***	***100 %***	***0.005 %***
TOTAL			**2.364.43**	**0.05**	**0.05**	**0.039**	**2,443.77**	**100 %**	**100 %**

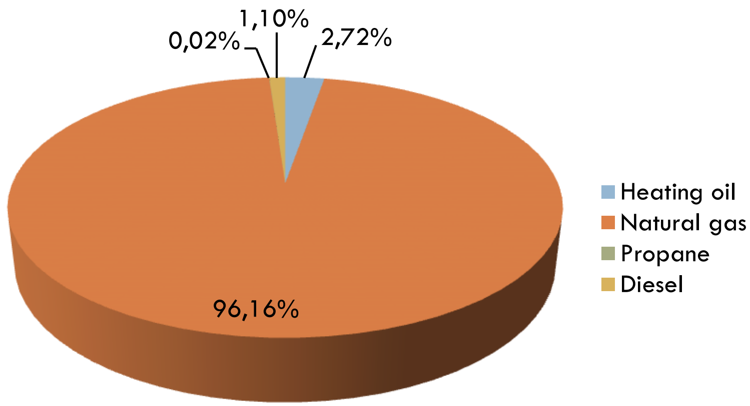


FIGURE 4-1: PROPORTION OF DIRECT GHG EMISSIONS FROM FOSSIL FUEL COMBUSTION IN BUILDINGS

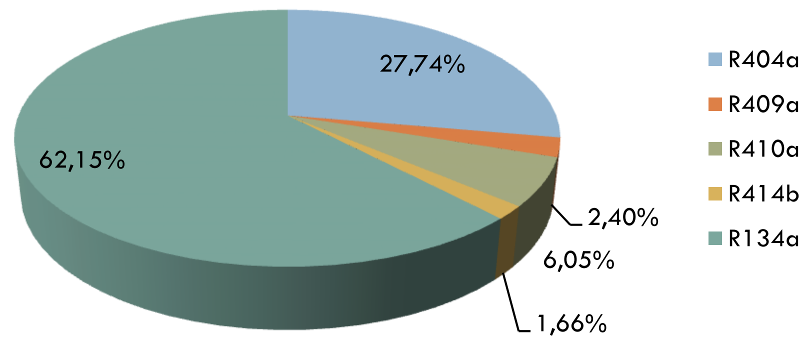


FIGURE 4-2: PROPORTION OF DIRECT GHG EMISSIONS FROM REFRIGERANT LEAKS IN AIR CONDITIONING SYSTEMS USED IN BUILDINGS

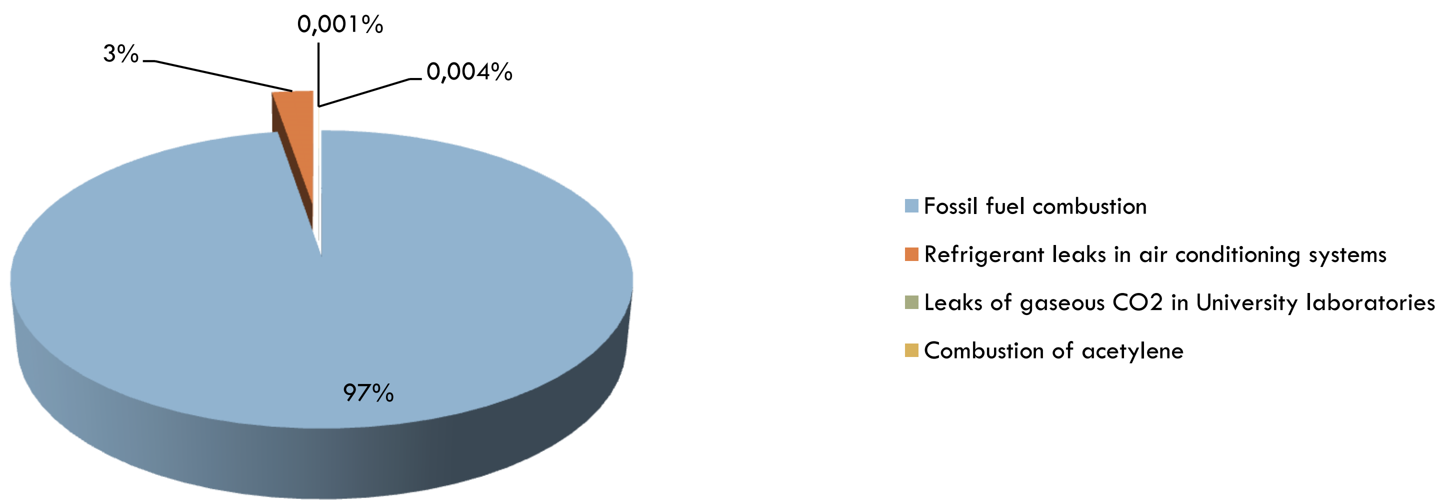


FIGURE 4-3: PROPORTION OF DIRECT GHG EMISSIONS PER SOURCE (BUILDINGS)

4.1.2 Motorised mobile equipment

TABLE 4-2: DIRECT GHG EMISSIONS FOR MOTORISED MOBILE EQUIPMENT

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total direct emissions
Fossil fuel combustion									
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	11,693.6	liters	26.77	0.002	0.0003	-	27.27	46.59 %	45.16 %
Gasoline combustion – Off-road vehicles	5,611.2	liters	12.8	0.02	0.0003	-	13.20	22.55 %	21.86 %
Diesel combustion – Light-duty trucks (Advanced control)	2,994.5	liters	8.0	0.0002	0.0007	-	8.20	14.01 %	13.58 %
Diesel combustion – Off-road vehicles	998.2	liters	2.7	0.0001	0.001	-	3.00	5.13 %	4.97 %
Propane combustion – Off-road vehicles (Zamboni)	4,708.6	liters	7.11	0.003	0.0001	-	7.21	12.32 %	11.94 %
SUB-TOTAL			***57.35***	***0.02***	***0.002***	-	***58.53***	***100*** %	***96.94*** %
Refrigerant leaks in air conditioning systems									
R134a	10	systems	-	-	-	0.001	1.85	100 %	3.06 %
SUB-TOTAL			-	-	-	***0.001***	***1.85***	***100*** %	***3.06*** %
TOTAL			**57.35**	**0.02**	**0.002**	**0.001**	**60.38**	**100 %**	**100 %**

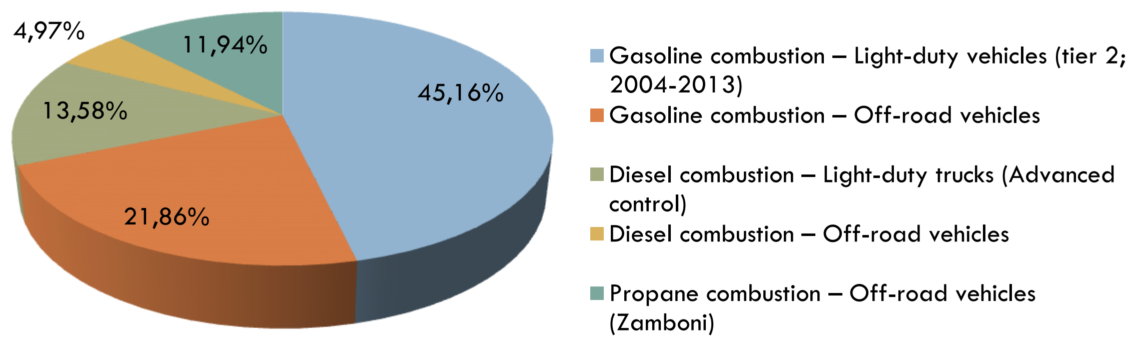


FIGURE 4-4: PROPORTION OF DIRECT GHG EMISSIONS PER TYPES OF VEHICLES

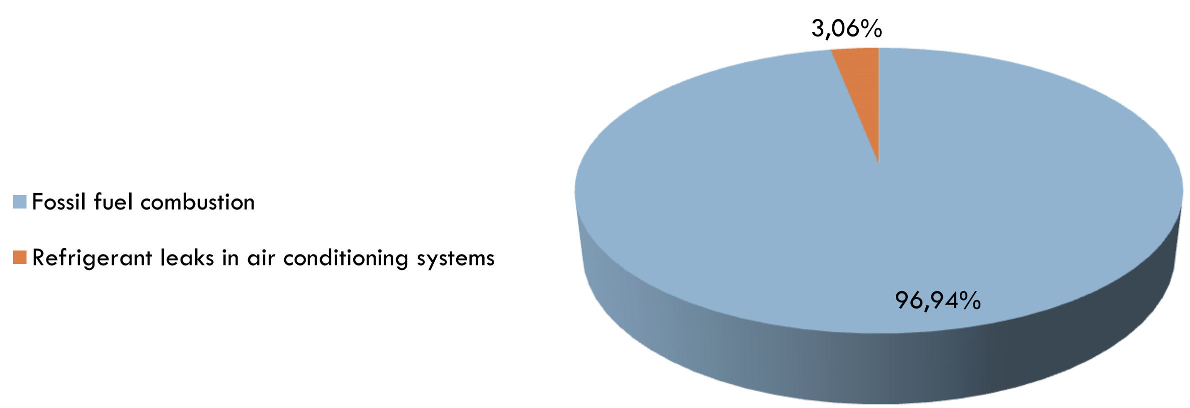


FIGURE 4-5: PROPORTION OF DIRECT GHG EMISSIONS PER SOURCES (MOTORISED MOBILE EQUIPMENT)

4.2 Quantification of GHG emissions from indirect energy

4.2.1 Buildings

TABLE 4-3: GHG EMISSIONS FROM INDIRECT ENERGY SOURCES

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total indirect energy emissions
Electricity production and consumption									
Electricity production and consumption	10,422,000	kWh	17.26	0.002	0.001	-	17.63	100 %	100 %
SUB-TOTAL			***17.26***	***0.002***	***0.001***	-	***17.63***	***100 %***	***100 %***
TOTAL			**17.26**	**0.002**	**0.001**	**-**	**17.63**	**100 %**	**100 %**

4.3 Quantification of other indirect energy GHG emissions

4.3.1 Buildings

TABLE 4-4: OTHER INDIRECT GHG EMISSIONS IN BUILDINGS

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total other indirect energy emissions
Fossil fuel production (complete cycle, except finale use)									
Heating oil	23,648.10	liters	-	-	-	-	12.1	2.38 %	2.38 %
Natural gas	1,211,156.00	m^3	-	-	-	-	487.9	96.12 %	96.12 %
Propane	312.18	liters	-	-	-	-	0.1	0.02 %	0.02 %
Diesel	9,376.00	liters	-	-	-	-	7.4	1.46 %	1.46 %
SUB-TOTAL			-	-	-	-	***507.6***	***100 %***	***100 %***
TOTAL			**-**	**-**	**-**	**-**	**507.6**	**100 %**	**100 %**

4.3.2 Motorised mobile equipment

TABLE 4-5: OTHER INDIRECT GHG EMISSIONS FROM MOTORISED MOBILE EQUIPMENT

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total other indirect energy emissions
Fossil fuel production (complete cycle, except finale use)									
Gasoline	17,304.8	liters	-	-	-	-	12.5	72.67 %	72.67 %
Diesel	3,992.6	liters	-	-	-	-	3.2	18.60 %	18.60 %
Propane	4,708.6	liters	-	-	-	-	1.6	9.30 %	9.30 %
SUB-TOTAL			-	-	-	-	***17.2***	***100 %***	***100 %***
TOTAL			**-**	**-**	**-**	**-**	**17.2**	**100 %**	**100 %**

4.3.3 Landfilling, recycling, composting and transportation of waste

TABLE 4-6: OTHER INDIRECT GHG EMISSIONS FROM LANDFILLING, RECYCLING, COMPOSTING AND TRANSPORTATION OF WASTE

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total direct emissions
Landfilling, recycling and composting of waste									
Landfilling of waste material	200	tons	43.65[34]	4.72	-	-	99.12	70.85 %	67.01 %
Recycling of waste material	30	tons	-	-	-	-	25.69	18.36 %	17.37 %
Composting of waste material	85	tons	0.00	0.34	0.03	-	15.05	10.76 %	10.18 %
SUB-TOTAL			***43.65[32]***	***5.06***	***0.03***	-	***139.91***	***100 %***	***94.59 %***
Transportation of waste material (combustion of diesel in collection trucks)									
Waste material	1,169	liters	3.11	0.00013	0.00018	-	3.17	51.21 %	2.14 %
Recyclable material	13	liters	0.03	0.000001	0.000002	-	0.03	0.48 %	0.02 %
Compostable material	99	liters	0.26	0.00001	0.00002	-	0.27	4.36 %	0.18 %
Hazardous material	1,002	liters	2.67	0.0001	0.0002	-	2.72	43.94 %	1.84 %
SUB-TOTAL			***6.08***	***0.0003***	***0.0003***	-	***6.19***	***100 %***	***4.18 %***

[34] Not included into global other indirect GHG emissions since those results are from biomass.

Fossil fuel production (complete cycle, except finale use)									
Diesel	2,283	liters	-	-	-	-	1.8	100 %	1.22 %
SUB-TOTAL			-	-	-	-	***1.8***	***100 %***	***1.22 %***
TOTAL			**6.08**	**5.06**	**0.03**	**0.001**	**147.91**	**100 %**	**100 %**

4.3.4 Transportation of students and employees

TABLE 4-7: OTHER INDIRECT GHG EMISSIONS FROM STUDENTS AND EMPLOYEES TRANSPORTATION

SOURCES	QUANTITY		CO_2 EMISSIONS (t CO_2)	CH_4 EMISSIONS (t CH_4)	N_2O EMISSIONS (t N_2O)	HFC EMISSIONS (t HFC)	GHG EMISSIONS (t CO_2e)	CONTRIBUTION TO SUB-TOTAL EMISSIONS	CONTRIBUTION TO TOTAL DIRECT EMISSIONS
Fossil fuel combustion for home-to-campus travel of employees									
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	380,794	liters	871.64	0.05	0.008	-	875.35	87.76 %	25.49 %
Diesel combustion – Heavy-duty trucks (Advanced control)	45,036	liters	119.64	0.005	0.007	-	122.14	12.24 %	3.56 %
SUB-TOTAL			***991.57***	***0.06***	***0.02***	-	***997.49***	***100 %***	***29.05 %***
Fossil fuel combustion for travel of employees on the job									
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	50,720	liters	116.10	0.007	0.001	-	116.59	100 %	3.40 %
SUB-TOTAL			***116.10***	***0.007***	***0.001***	-	***116.59***	***100 %***	***3.40 %***
Fossil fuel combustion for home-to-campus travel of student									
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	324,227	liters	661.85	0.04	0.006	-	664.67	43.05 %	19.36 %
Diesel combustion – Heavy-duty trucks (Advanced control)	289,143	liters	863.42	0.04	0.05	-	879.34	56.95 %	25.61 %
SUB-TOTAL			***1,525.26***	***0.08***	***0.06***	-	***1,544.01***	***100 %***	***44.97 %***
Fossil fuel production (complete cycle, except finale use)									
Gasoline	669,936	liters	-	-	-	-	483.32	62.32 %	14.08 %
Diesel	369,263	liters	-	-	-	-	292.28	37.68 %	8.51 %
SUB-TOTAL			-	-	-	-	***775.60***	***100 %***	***22.59 %***
TOTAL			**2,632.93**	**0.14**	**0.07**	**-**	**3,433.70**	**100 %**	**100 %**

4.3.5 Production and transport of office paper

TABLE 4-8: OTHER INDIRECT GHG EMISSIONS FROM PRODUCTION AND TRANSPORT OF OFFICE PAPER

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total other indirect emissions
Production of office paper									
Paper sheets of 8.5"x11" with 50% recycled content	1,400,000	sheets	-	-	-	-	14.52	37.92 %	37.83 %
Paper sheets of 8.5"x11" with 30% recycled content	1,635,000	sheets	-	-	-	-	18.49	48.29 %	48.18 %
Paper sheets of 8.5"x14" with 30% recycled content	105,000	sheets	-	-	-	-	1.51	3.94 %	3.93 %
Paper sheets of 11"x17" with 30% recycled content	70,000	sheets	-	-	-	-	1.59	4.15 %	4.14 %
Paper sheets of 8.5"x11" with 100% recycled content	50,000	sheets	-	-	-	-	0.40	1.04 %	1.04 %
Paper sheets of 8.5"x11" with 10% recycled content	30,000	sheets	-	-	-	-	0.37	0.97 %	0.96 %
Paper sheets of 8.5"x11" with 0% recycled content	46,000	sheets	-	-	-	-	0.58	1.51 %	1.51 %
Paper sheets of 8.5"x14" with 0% recycled content	6,000	sheets	-	-	-	-	0.10	0.26 %	0.26 %
Paper sheets of 11"x17" with 0% recycled content	16,000	sheets	-	-	-	-	0.41	1.07 %	1.07 %
Paper sheets of 11"x17" with 10% recycled content	6,000	sheets	-	-	-	-	0.15	0.39 %	0.39 %
Paper sheets of 12"x18" with 10% recycled content	7,500	sheets	-	-	-	-	0.18	0.47 %	0.47 %
SUB-TOTAL			-	-	-	-	***38.29***	***100 %***	***99.77 %***
Fossil fuel combustion for transport of office paper									
Diesel combustion – Heavy-duty trucks (Advanced control)	26.62	liters	0.07	0.000003	0.000004	-	0.07	100 %	0.18 %
SUB-TOTAL			***0.07***	***0.000003***	***0.000004***	-	***0.07***	***100 %***	***0.18 %***
Fossil fuel production (complete cycle, except finale use)									
Diesel	26.62	liters	-	-	-	-	0.02	100 %	0.05 %
SUB-TOTAL			-	-	-	-	***0.02***	***100 %***	***0.05 %***
TOTAL			**0.07**	**0.000003**	**0.000004**	**-**	**38.38**	**100 %**	**100 %**

4.3.6 Drinkable water production

TABLE 4-9: OTHER INDIRECT GHG EMISSIONS FROM DRINKABLE WATER PRODUCTION

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total other indirect emissions
Drinkable water production									
Full-time faculty and staff	10,496	m^3/an	-	-	-	-	0.17	6.42 %	6.42 %
Part-time faculty	1,500	m^3/an	-	-	-	-	0.03	1.13 %	1.13 %
Part-time staff	1,908	m^3/an	-	-	-	-	0.03	1.13 %	1.13 %
Regular students	74,003	m^3/an	-	-	-	-	1.23	46.42 %	46.42 %
On-campus resident students	70,840	m^3/an	-	-	-	-	1.18	44.53 %	44.53 %
SUB-TOTAL			-	-	-	-	***2.65***	***100 %***	***100 %***
TOTAL			**-**	**-**	**-**	**-**	**2.65**	**100 %**	**100 %**

4.3.7 Wastewater treatment

TABLE 4-10: OTHER INDIRECT GHG EMISSIONS FROM WASTEWATER TREATMENT

Sources	Quantity		CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total other indirect emissions
Wastewaster treatment									
Full-time faculty and staff	275	employees	-	-	0.02	-	5.46	9.38 %	9.36 %
Part-time faculty	150	employees	-	-	0.01	-	2.98	5.12 %	5.11 %
Part-time staff	50	employees	-	-	0.003	-	0.99	1.70 %	1.70 %
Regular students	1,755	students	-	-	0.11	-	34.87	59.89 %	59.77 %
On-campus resident students	700	students	-	-	0.05	-	13.91	23.89 %	23.84 %
SUB-TOTAL			-	-	***0.19***	-	***58.22***	***100 %***	***99.79 %***
Energy consumption at wastewater treatment facilities									
Electricity consumption	72.816	kWh	0.12	0.00001	0.00001	-	0.12	100 %	0.21%
SUB-TOTAL			***0.12***	***0.00001***	***0.00001***	-	***0.12***	***100 %***	***0.21 %***
TOTAL			**0.12**	**0.00001**	**0.19**	**-**	**58.34**	**100 %**	**100 %**

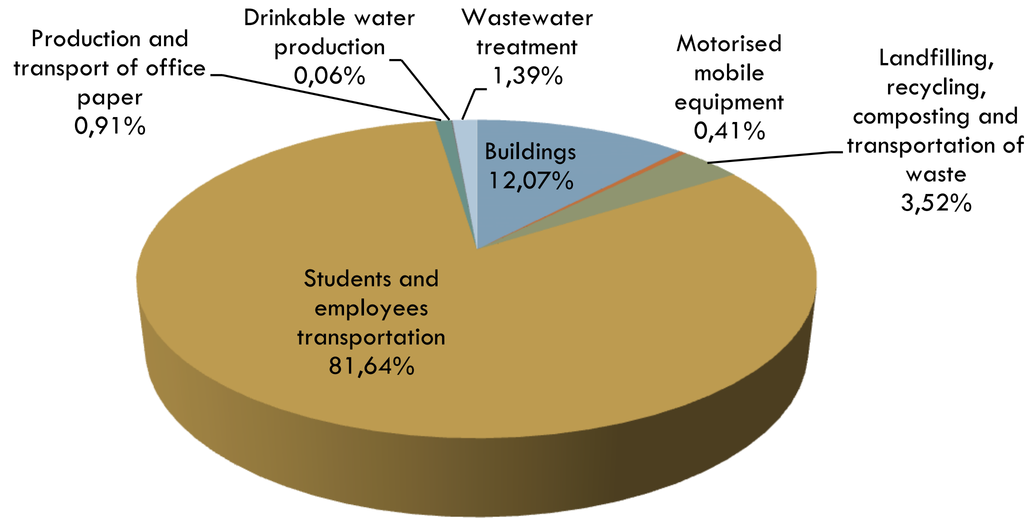


FIGURE 4-6: PROPORTION OF OTHER INDIRECT GHG EMISSIONS PER CATEGORY

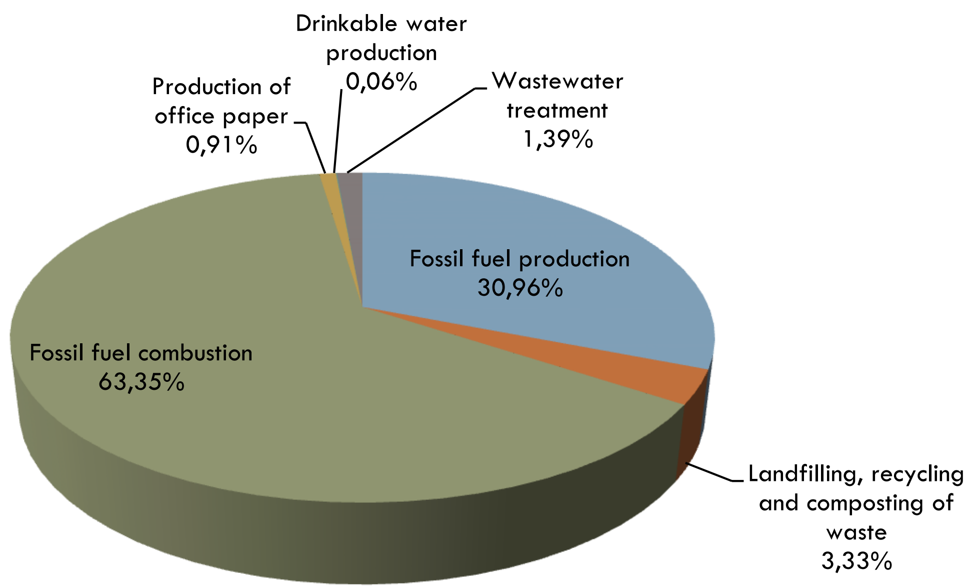


FIGURE 4-7: PROPORTION OF OTHER INDIRECT GHG EMISSIONS PER SOURCES

4.4 Total of Bishop's University GHG emissions in 2012

TABLE 4-11: TOTAL OF BISHOP'S UNIVERSITY GHG EMISSIONS IN 2012 PER SOURCES AND CATEGORIES

Emission types	Sources	CO_2 Emissions (t CO_2)	CH_4 Emissions (t CH_4)	N_2O Emissions (t N_2O)	HFC Emissions (t HFC)	GHG Emissions (t CO_2e)	Contribution to sub-total emissions	Contribution to total GHG emissions
Buildings								
Direct	Fossil fuel combustion	2,364.43	0.05	0.05	-	2,379.95	80.16 %	35.38 %
Direct	Refrigerant leaks in air conditioning systems	-	-	-	0.039	63.69	2.15 %	0.95 %
Direct	Leaks of gaseous CO2 in University's laboratories	-	-	-	-	0.02	0.001 %	0.0004 %
Direct	Combustion of acetylene	-	-	-	-	0.10	0.004 %	0.002 %
Indirect energy	Electricity production and consumption	17.26	0.002	0.001	-	17.63	0.59 %	0.26 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	507.60	17.10	7.55 %
	SUB-TOTAL	***2,381.69***	***0.05***	***0.05***	***0.039***	***2,969.00***	***100 %***	***44.13 %***
Motorised mobile equipment								
Direct	Fossil fuel combustion	57.35	0.02	0.002	-	58.53	75.44 %	0.87 %
Direct	Refrigerant leaks in air conditioning systems	-	-	-	0.001	1.85	2.38 %	0.03 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	17.20	22.17 %	0.26 %
	SUB-TOTAL	***57.35***	***0.02***	***0.02***	***0.001***	***77.58***	***100 %***	***1.15 %***
Landfilling, recycling, composting and transportation of waste								
Other indirect	Landfilling, recycling and composting of waste	43.65*	5.06	0.03	-	139.91	94.59 %	2.08 %
Other indirect	Fossil fuel combustion (transportation of waste)	6.08	0.0003	0.0003	-	6.19	4.18 %	0.09 %
Other indirect	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	1.80	1.22 %	0.03 %
	SUB-TOTAL	***6.08***	***5.06***	***0.03***	***-***	***147.91***	***100 %***	***2.20 %***

Students and employees transportation

Other indirect	Fossil fuel combustion	2,632.93	0.14	0.07	-	2,658.09	77.42 %	39.51 %
	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	775.60	22.59 %	11.83 %
	SUB-TOTAL	***2,632.93***	***0.14***	***0.07***	**-**	***3,433.70***	***100 %***	***51.04 %***

*Production and transport of office paper***

Other indirect	Production of office paper	-	-	-	-	38.29	99.77 %	0.57 %
	Fossil fuel combustion	0.07	0.000003	0.000004	-	0.07	0.18 %	0.001 %
	Fossil fuel production (complete cycle, except finale use)	-	-	-	-	0.02	0.05 %	0.0003 %
	SUB-TOTAL	***0.07***	***0.000003***	***0.000004***	**-**	***38.38***	***100 %***	***0.57 %***

Drinkable water production

Other indirect	Drinkable water production	-	-	-	-	2.65	100 %	0.04 %
	SUB-TOTAL	**-**	**-**	**-**	**-**	***2.65***	***100 %***	***0.04 %***

*Wastewater treatment****

Other indirect	Wastewater treatment	-	-	0.19	-	58.22	99.79 %	0.87 %
	Energy consumption of wastewater facilities	0.12	0.00001	0.00001	-	0.12	0.21 %	0.002 %
	SUB-TOTAL	***0.12***	***0.00001***	***0.19***	**-**	***58.34***	***100 %***	***0.87 %***
	TOTAL	**5,078.37**	**5.27**	**0.34**	**0.04**	**6,727.54**	**-**	**100 %**

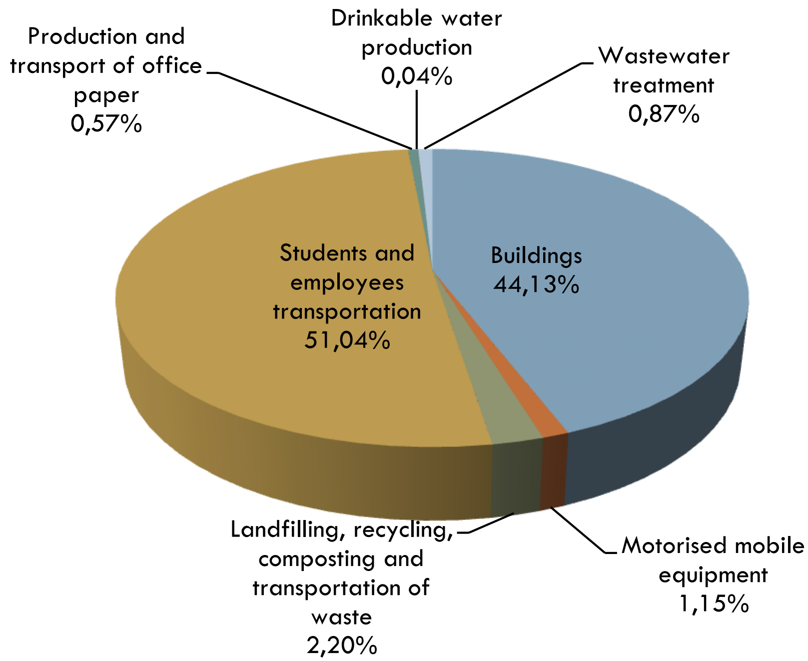


FIGURE 4-8: SUMMARY OF GHG EMISSIONS PER CATEGORY

TABLE 4-12: SUMMARY OF GHG EMISSIONS PER CATEGORY

	GHG Emissions (tCO_2e)	Contribution to total GHG emissions
Buildings	2,969.00	44.13%
Motorised mobile equipment	77.58	1.15%
Landfilling, recycling, composting and transportation of waste	147.91	2.20%
Students and employees transportation	3,433.70	51.04%
Production and transport of office paper	38.38	0.57%
Drinkable water production	2.65	0.04%
Wastewater treatment	58.34	0.87%
TOTAL	**6,727.56**	**100%**

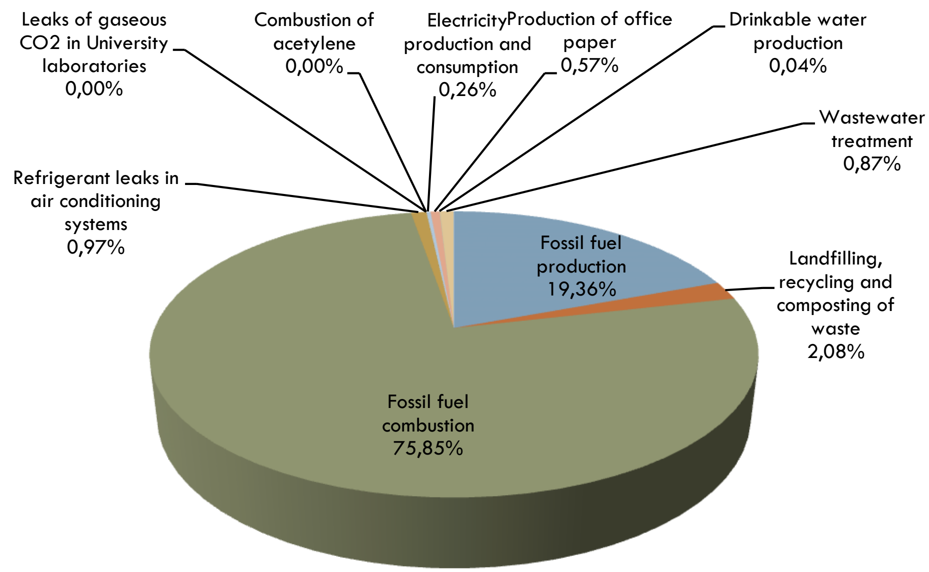


FIGURE 4-9: SUMMARY OF GHG EMISSIONS PER SOURCES

TABLE 4-13: SUMMARY OF GHG EMISSIONS PER SOURCES

	GHG Emissions (tCO_2e)	Contribution to total GHG emissions
Fossil fuel production	1,302.22	19.36%
Landfilling, recycling and composting of waste	139.91	2.08%
Fossil fuel combustion	5,102.83	75.85%
Refrigerant leaks in air conditioning systems	65.54	0.97%
Leaks of gaseous CO_2 in University's laboratories	0.13	0.002%
Electricity production and consumption	17.63	0.26%
Production of office paper	38.29	0.57%
Drinkable water production	2.65	0.04%
Wastewater treatment	58.34	0.87%
TOTAL	**6,727.56**	**100%**

5 BASE-YEAR OF BISHOP'S UNIVERSITY GHG INVENTORY

This GHG inventory has been elaborated on a one-year basis, from January 1st to December 31st, 2012. It is the base-year reference for future GHG inventories as it is the first to be quantified by the organization. The year 2012 was selected for data availability reasons.

Base-year will be recalculated if new GHG emission sources are included in the following years or if quantification methodologies are modified. Recalculation methodologies will be developed according to the availability of data at the time of recalculation.

6 UNCERTAINTIES

Table 6-1 was used to qualify the uncertainty level for each GHG quantification. Uncertainty levels were defined as follows[35]:

TABLE 6-1: DEGREES OF UNCERTAINTY

Level	Uncertainty
Low	± 5 %
Medium	± 15 %
High	± 30 %

For this GHG inventory, these values are used in the global uncertainty analysis (table 6-2).

The uncertainty level depends on the selected key data in quantification. Direct GHG emissions and GHG emissions from indirect energy were derived from energy bills (Gaz Métro, Hydro-Québec, etc.). Since all purchased energy by Bishop's is consumed on site, those key data are considered precise with a low level of uncertainty. Leaks from refrigeration systems were estimated without key data from actual observations but by average observations. Thus, the associated level of uncertainty is medium. Uncertainty level associated with indirect GHG emissions is principally rated as medium as calculation and data manipulation are often required. To reduce uncertainty level, Bishop's University should:

- Systematically characterize landfilled, recycled, and composted quantities of waste
- Verify actual daily travel habits of student, faculties, and staff
- Quantify drinking water consumption on campus with specialized monitoring equipment

[35] Despite their subjectivity, those values are usually proposed by the GHG Protocol.

TABLE 6-2: UNCERTAINTY ANALYSIS OF GHG EMISSIONS

SOURCES		GHG Emissions (tCO_2e)	UNCERTAINTY
DIRECT greenhouse gases emissions			
Fossil fuel combustion	Heating oil	64.68	± 5 %
	Natural gas	2,288.63	± 5 %
	Propane	7.69	± 5 %
	Gasoline	40.47	± 5 %
	Diesel	37.36	± 5 %
Refrigerant leaks in air conditioning systems	R404a	17.67	± 15 %
	R409a	1.53	± 15 %
	R410a	3.85	± 15 %
	R414b	1.06	± 15 %
	R134a	41.43	± 15 %
Leaks of gaseous CO_2 in University's laboratories	Acetylene	0.10	± 15 %
	Gaseous CO_2	0.01	± 15 %
	Dry ice	0.01	± 15 %
Greenhouse gases emissions from INDIRECT ENERGY			
Production and transmissions of electricity	Quebec's Production and transmissions of electricity	17.63	± 5 %
OTHER INDIRECT ENERGY greenhouse gases emissions			
Fossil fuel production	Heating oil	12.10	± 5 %
	Natural gas	487.90	± 5 %
	Propane	1.7	± 5 %
	Gasoline	495.82	± 5 %
	Diesel	304.7	± 5 %
Fossil fuel combustion	Gasoline	1,656.61	± 5 %
	Diesel	1,007.74	± 5 %
Waste landfilling	Waste landfilling	99.12	± 15 %
Waste recycling	Waste recycling	25.69	± 15 %
Waste composting	Waste composting	15.05	± 15 %
Production of office paper	Production of office paper	38.29	± 5 %
Drinkable water production	Drinkable water production	2.65	± 15 %
Wastewater treatment	Wastewater treatment	58.34	± 15 %

7 GHG INVENTORY MANAGEMENT

Figure 7-1 shows the principal components to consider for the realization of an efficient GHG inventory management. In the attempt to minimize the level of uncertainty of quantification and thus to improve their quality, Bishop's University should consider the following guidelines.

FIGURE 7-1 : COMPONENTS FOR AN EFFICIENT GHG EMISSIONS INVENTORY MANAGEMENT SYSTEM

These components can be described as:

- GHG emissions management guidelines manual: Documentation referring to a step-by-step method for the realization of Bishop's University GHG inventories.
- Data management system: A method to harmonize data collection and management of necessary data in Bishop's University GHG inventories.
- GHG inventory quality management system: Systematic process for the continuous improvement of GHG inventory quality.

7.1 GHG emissions management guidelines manual

The GHG emissions management guidelines manual includes Bishop's University policies, strategies, and objectives concerning GHG emissions management and reduction. It also contains fundamental principles of the GHG inventory, guidelines for quantification, data managements system, and GHG verification (if applicable). An example of table of content for this type of document can be found in annex IV.

7.2 Data management system

The GHG data management system is designed to facilitate monitoring, control, documentation, and verification of GHG emissions data. It includes:

- Policies, processes and methods to determine, manage, and update GHG information
- Monitoring devices, registry papers, software, digital calculator sheets, calculation algorithms, etc.
- Data, receipts, bills, compiled information, etc.
- Operational methods

7.3 GHG inventory quality management system

The GHG inventory quality management system is a systematic process used to:

- Prevent and correct errors
- Identify opportunities for the improvement of the GHG inventory quality and reliability
- Assure the application of the five ISO 14064-1 fundamental principles (relevance, completeness, consistency, accuracy, transparency)
- improve:
  - Quantification and data collection methods
  - Data and emission factors
  - Related processes and systems (ex: GHG inventory preparation process)
  - Documentation (ex: GHG emissions management guidelines manual)

According to the *GHG Protocol*, GHG inventory quality management should be done following those specific seven steps:

1. Build an official management team responsible for the GHG inventory quality
2. Develop a specific GHG inventory quality management plan
3. Hold regular and general monitoring activities
4. Hold specific monitoring activities for certain emission sources
5. Review estimation made in GHG inventories and reports
6. Apply a retroaction process for concerned actors to facilitate amelioration and to correct detected errors.
7. Establish data conservation system for intra- and extra-organization information and communication.

To assure the realisation of reliable, accurate and up-to-date GHG emissions inventories, Bishop's University could include, in its GHG reduction action plan, the application of this specific GHG inventory management process.

8 CONCLUSION

In total, the activities related to Bishop's University have generated 6,728 tCO_2e in 2012, which are segregated into the following: 2,504 tCO_2e in direct emission, 18 tCO_2e in energy indirect emissions, and 4,206 tCO_2e in other indirect emission.

The items included in the inventory are buildings, motorized equipment, the University community traveling, the waste management, wastewater treatment, paper consumption, water consumption, and fossil fuel production.

The results for the 2012 GHG inventory show that student and staff travels are the most important item in terms of GHG emissions. This traveling accounts for 2,658 tCO_2e, which is equivalent to about 40 % of total GHG emissions.

The other two elements that are responsible for a significant share of total GHG emissions from Bishop's University are buildings and fossil fuels production. These two elements represent 2,461 tCO_2e (about 37 % of the total) and 1,302 tCO_2e (about 19 % of the total). With regard to buildings, the combustion of natural gas used primarily for space heating is the main source of emissions (95 %) with 2,380 tCO_2e.

GHG emissions intensity of Bishop's University per person, students and staff included, is presented in the following table and can be used for further year-to-year comparison:

TABLE 8-1: GHG EMISSIONS INTENSITY OF BISHOP'S UNIVERSITY PER PERSON FOR 2012

	Intensity (tCO_2e/pers.)
Direct emission intensity	0.85
Energy indirect emission intensity	0.01
Other indirect emission intensity	1.44
Global emission intensity	2.30

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Annex I: GHG data collection actors

Name	Service	Information
Michel Caron	Bishop's University *Director, Buildings and Grounds Services*	Tél. : (819) 822-9600 ext. 2549 michel.caron@ubishops.ca
Angela Lanza	Bishop's University *Sustainable Development Student Intern*	Tél. : (819) 822-9600 ext. 2195 SDSI@ubishops.ca
Mathieu Muir	Enviro-access *Project director*	Tél. : (819) 823-2230 ext. 33 mmuir@enviroaccess.ca
Nicolas Vincent	Enviro-access *Technical advisor*	Tél. : (514) 284-5794 ext. 21 nvincent@enviroaccess.ca
Isabelle Audet	Enviro-access *Technical advisor*	Tél. : (819) 823-2230 ext. 30 iaudet@enviroaccess.ca

Annex II: Global Warming Potentials

GHG	Chemical formula	GWP
Carbone dioxide	CO_2	**1**
Methane	CH_4	**21**
Nitrous oxide	N_2O	**310**
Sulfur hexafluoride	SF_6	**23 900**
Hydrofluorocarbons (HFCs)		
HFC-23	CHF_3	**11 700**
HFC-32	CH_2F_2	**650**
HFC-41	CH_3F	**150**
HFC-43-10-mee	$C_5H_2F_{10}$	**1 300**
HFC-125	C_2HF_5	**2 800**
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	**1 000**
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	**1 300**
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	**300**
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	**3 800**
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	**140**
HFC-227ea	C_3HF_7	**2 900**
HFC-236fa	$C_3H_2F_6$	**6 300**
HFC-245ca	$C_3H_3F_5$	**560**
HFC-404a	$CHF_2CF_3/CH_2CF_3/CH_2FCF_3$	**3 260**
HFC-409a	$CHClF_2/CHClFCF_3/CH_3CClF_2$	**1 288**
HFC-410a	CH_2F_2/CF_3CHF_2	**1 730**
HFC414b	$CHClF_2/C_2HClF_4/C_2H_3ClF_2/C_4H_{10}$	**1 200**
Perfluorocarbons (PFCs)		
Perfluoromethane	CF_4	**6 500**
Perfluoroethane	C_2F_6	**9 200**
Perfluoropropane	C_3F_8	**7 000**
Perfluorobutane	C_4F_{10}	**7 000**
Perfluorocyclobutane	c-C_4F_{10}	**8 700**
Perfluoropentane	C_5F_{12}	**7 500**
Perfluorohexane	C_6F_{14}	**7 400**

Annex III: GHG emission factors

COMPONENT	CO_2 EMISSION FACTOR	CH_4 EMISSION FACTOR	N_2O EMISSION FACTOR	CO_2E EMISSION FACTOR	GWP	UNCERTAINTY	REFERENCE
DIRECT GHG emissions							
Global warming potential of principal GHG							
CO_2 emissions	S.O.				1 kg CO_2 éq/kg	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
CH_4 emissions	S.O.				21 kg CO_2 éq/kg	Low	
N_2O emissions	S.O.				310 kg CO_2 éq/kg	Low	
Fossil fuel combustion in buildings							
Natural gas	1.88 kgCO_2/m^3	0.000037 kgCH_4/m^3	0.000035 kgN_2O/m^3	1.89 kgCO_2e/m^3	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Heating oil	2.73 kgCO_2/L	0.000026 kgCH_4/L	0.000031 kgN_2O/L	2.74 kgCO_2e/L	S.O.	Low	
Diesel	2.66 kgCO_2/L	0.00013 kgCH_4/L	0.000400 kgN_2O/L	2.79 kgCO_2e/L	S.O.	Low	
Propane (residential)	1.51 kgCO_2/L	0.000027 kgCH_4/L	0.000108 kgN_2O/L	1.54 kgCO_2e/L	S.O.	Low	
Fossil fuel combustion in motorised mobile equipment							
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	2.29 kgCO_2/L	0.000140 kgCH_4/L	0.000022 kgN_2O/L	2.30 kgCO_2e/L	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Gasoline combustion – Off-road vehicles	2.29 kgCO_2/L	0.002700 kgCH_4/L	0.000050 kgN_2O/L	2.36 kgCO_2e/L	S.O.	Low	
Diesel combustion – Light-duty trucks (Advanced control)	2.66 kgCO_2/L	0.000068 kgCH_4/L	0.000220 kgN_2O/L	2.73 kgCO_2e/L	S.O.	Low	
Diesel combustion – Off-road vehicles	2.66 kgCO_2/L	0.000150 kgCH_4/L	0.001100 kgN_2O/L	3.01 kgCO_2e/L	S.O.	Low	
Propane combustion – Off-road vehicles (Zamboni)	1.51 kgCO_2/L	0.000640 kgCH_4/L	0.000028 kgN_2O/L	1.53 kgCO_2e/L	S.O.	Low	
Refrigerant leaks in air conditioning systems							

R404a	S.O.	3,260	kg CO_2e/kg	Low	**United Nations Environment Programme (UNEP), 2011.** *2010 REPORT OF THE REFRIGERATION, AIR CONDITIONING AND HEAT PUMPS TECHNICAL OPTIONS COMMITTEE. Table 2-1: GWP and physical data of refrigerants. ISBN: 978-9966-20-002-0.* and **Canadian Standard Association, 2006**. ISO 14064-1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removal
R409a	S.O.	1,288	kg CO_2e/kg	Low	
R410a	S.O.	1,730	kg CO_2e/kg	Low	
R414b	S.O.	1,200	kg CO_2e/kg	Low	
HFC134a	S.O.	1,300	kg CO_2e/kg	Low	
Combustion of acetylene and use of gaseous CO_2 and dry ice in University's laboratories					
Combustion of acetylene	**See calculation in Excel sheet "Bâtiments - Données"**				

GHG emissions from INDIRECT ENERGY sources											
Production and transmission of electricity											
Quebec's Production and transmissions of electricity	0.002	kg CO_2/kWh	0.0000002	kg CH_4/kWh	0.0000001	kg N_2O/kWh	0.002	kg/kWh	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada*. Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064 *(Part 3, Table A13-6) :*

OTHER INDIRECT GHG emissions											
Home-to-campus and on the job travel of employees and students											
Gasoline combustion – Light-duty vehicles (tier 2; 2004-2013)	2.29	kgCO_2/L	0.00014	kgCH_4/L	0.000022	kgN_2O/L	2.30	kgCO_2e/L	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada*. Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064
Diesel combustion – Heavy-duty trucks (bus) (Advanced control)	2.66	kgCO_2/L	0.00011	kgCH_4/L	0.00015	kgN_2O/L	2.71	kgCO_2éq/L	S.O.	Faible	
Landfilling, recycling and composting of waste											

Landfilling of waste material	Caculated with LandGEM								S.O.	Medium	**U.S. Environmental Protection Agency (EPA). 2005.** *Landfill Gas Emission Model, Version 3.02*
Compostage de la matière organique	0.00	kgCO_2/t	4.0000	kgCH_4/t	0.30000	kgN_2O/t	177.00	kgCO_2 éq/t	S.O.	Medium	**IPCC, 2006.** *Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 4: Biological treatment of solid waste*
Plastic recycling (1 to 5])[1]	S.O.						0.58	kgCO_2 éq/kg	S.O.	Medium	**ICF Consulting. 2005.** *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update - Draft Report* (Exhibit ES-2)
Paper recycling[2]	S.O.						0.89	kgCO_2 éq/kg	S.O.	Medium	
Carton recycling	S.O.						0.86	kgCO_2 éq/kg	S.O.	Medium	
Metal recycling[5]	S.O.						0.94	kgCO_2 éq/kg	S.O.	Medium	
Glass recycling	S.O.						0.30	kgCO_2 éq/kg	S.O.	Medium	
Fossil fuel production											
Natural gas production	S.O.						0.40	kgCO_2 éq/m^3	S.O.	Low	**Ressources Naturelles Canada. 2013.** GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 (Onglet "Upstream results HHV", cellule CS20)
Heating oil production	S.O.						0.51	kgCO_2 éq/L	S.O.	Low	**Ressources Naturelles Canada. 2013.** GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 (Onglet "Upstream results HHV", cellule I20)
Propane production	S.O.						0.33	kgCO_2 éq/L	S.O.	Low	**Ressources Naturelles Canada. 2013.** GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 (Onglet "Upstream results HHV", cellule M20 et onglet "Fuel Char", cellule B136)
Diesel production	S.O.						0.79	kgCO_2 éq/L	S.O.	Low	**Ressources Naturelles Canada. 2013.** GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 (Onglet "Upstream results HHV", cellule F20 et onglet "Fuel Char", cellule B92)

Gasoline production (low S)	S.O.						0.72	$kgCO_2$ éq/L	S.O.	Low	**Ressources Naturelles Canada. 2013.** GHGenius - A model for lifecycle assessment of transportation fuels. Version 4.03. 2013 (Onglet "Upstream results HHV", cellule D20 et onglet "Fuel Char", cellule B114)
Transport of waste material											
Diesel combustion – Heavy-duty trucks (Advanced control)	2.66	$kgCO_2$ /L	0.000110	$kgCH_4$ /L	0.000151	kgN_2O /L	2.71	$kgCO_2$ éq/L diesel	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064 (Table A8-11)
Production and transport of office paper											
Paper production 100% recycled content - 8½x11	S.O.						4.01	$kgCO_2$ e/pqt	S.O.	Medium	**Ministry of Environment, 2012.** *2012 B.C. Practices Methodology for Quantifying Greenhouse Gas Emissions - Including Guidance for Public Sector Organizations, Local Governments and Community Emissions.*
Paper production 50% recycled content - 8½x11	S.O.						5.18	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 30% recycled content - 8½x11	S.O.						5.65	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 30% recycled content - 8½x14	S.O.						7.20	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 30% recycled content - 11x17	S.O.						11.33	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 10% recycled content - 8½x11	S.O.						6.12	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 10% recycled content - 11x17	S.O.						12.27	$kgCO_2$ e/pqt	S.O.	Medium	
Paper production 0% recycled content - 8½x11	S.O.						6.36	$kgCO_2$ e/pqt	S.O.	Medium	

Paper production 0% recycled content - 8½x14	S.O.						8.09	kgCO$_2$e/pqt	S.O.	Medium	
Paper production 0% recycled content - 11x17	S.O.						12.74	kgCO$_2$e/pqt	S.O.	Medium	
Diesel combustion – Heavy-duty trucks (Advanced control)	2.66	kg CO$_2$/L	0.000110	kg CH$_4$/L	0.000151	kgN$_2$O/L	2.71	kgCO$_2$e/L	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064 (Table A8-11)
Drinkable water production											
Drinkable water production[3]	S.O.						0.02	kgCO$_2$e/m^3	S.O.	High	**Logé, H. 2006.** *Plan d'action corporatif « Pour préserver le climat »*, Ville de Montréal, Service des infrastructures, transport et environnement, p.27 (Tableau 4).
Wastewater treatment											
Wastewater treatment	0.00	kgCO$_2$/pers.·year	1.97	kgCH$_4$/pers.·year[4]	0.064	kgN$_2$O/pers.·year	61.26	kgCO$_2$e/pers.·year	S.O.	Low	**Environment Canada. 2013.** *National Inventory Report 1990-2011 (Part 2): Greenhouse Gas Sources and Sinks in Canada.* Ottawa : Pollutant Inventories and Reporting Division, 2013. ISSN: 1910-7064

[1]Considered 33 % HDPE, 36 % PET and 31 % others. Based on data from RECYC-QUÉBEC.
[2]Considered 38 % fine paper, 14 % newpapers and 48 % carton. Based on data from RECYC-QUÉBEC.
[3]Mean GHG emissions for six treatment facilities from City of Montreal.
[4]Considered only for anaerobic treatment (not included for Bishop's University).
[5]Considered 88 % steel and 12 % aluminium. Based on data from RECYC-QUÉBEC.

ANNEXE IV: example of table of content to a GHG emissions management guidelines manual

TABLE OF CONTENT

8. Guidelines to GHG declaration

- Public GHG Reports
- GHG Reports presented to Bishop's University managers
- GHG verification reports

9. Process for the GHG inventory update

10. GHG verification guidelines

- Standards and protocols used for verification
- Objectives and criteria for verification
- Assurance level

11. Choice of the verificator