MINISTÈRE DE L'ENVIRONNEMENT, DE LA LUTTE CONTRE LES CHANGEMENTS CLIMATIQUES, DE LA FAUNE ET DES PARCS

Greenhouse Gas Emissions

# **Quantification Guide**

February, 2025





# **PRODUCTION TEAM**

Direction générale de l'expertise en transition climatique et énergétique

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# **TABLE OF CONTENTS**

TERM	S AND	DEFINITIC	DNS	1
ACRO	NYMS	AND ABBI	REVIATIONS	5
1	Introduction			
2	GENERAL CONCEPTS			
	2.1 GHG to Consider			
	22	Direct an	d Indirect GHG Emissions	8
		2.2.1	Direct GHG Emissions	
		2.2.2	Indirect GHG Emissions from Electricity Consumption	8
		2.2.3	Upstream, Downstream or Life-cycle Indirect GHG Emissions	9
	2.3	GHG Em	ission Sources	9
		2.3.1	Combustion GHG Emissions	9
		2.3.2	GHG Emissions from Industrial Processes	10
		2.3.3	Other GHG Emissions	
		2.3.4	The Specific Case of Biogenic CO <sub>2</sub> Emissions	
		2.3.5	Examples of Emission Sources by Implementation Phase	11
		2.3.6	Examples of Emission Sources Associated with Different GHGs	11
		2.3.7	Exclusions	
	2.4	.4 Quantification Approach		12
2.5 Quantification Reports		ation Reports		
		2.5.1	To Assess the Impacts of GHG Emissions from an Activity or Project	13
		2.5.2	For GHG Emissions Reduction Projects	14
	2.6	Compete	ent Person for GHG Emissions Quantification	
	2.7	Presentation of Results and Global Warming Potentials		15
	2.8	GHG Em	issions Intensity	
3	QUAN	TIFICATIO	DN OF GHG EMISSIONS	
	3.1	Emission	s from Stationary Combustion Systems	
	3.2	Emission	s from Mobile Combustion Systems	
	3.3	Indirect GHG Emissions from Electrical Energy Consumption		
	3.4	GHG Emissions from Industrial Processes		
	3.5 GHG Emissions from Mining and Mineral Processing			
		3.5.1	Calculation of GHG emissions from iron pellet production	
		3.5.2	Calculation of GHG emissions from the use of carbonates in a process	25
		3.5.3	. Other GHG emissions from mineral processing	
		3.5.4	GHG Emission Factors from Commonly Used Mineral Products Production	
		3.5.5	GHG Emission Factors from the Iron and Steel Industry	
		3.5.6	GHG Emission Factors for Aluminium Production	
	3.6	GHG Em	issions from Hydrogen Production and Use	27

	3.6.1	Hydrogen	Production and Use	27		
	3.6.2	Evolution	of Knowledge on Hydrogen	28		
3.7	GHG Emissions from the Chemical Industry			29		
3.8	GHG Emissions from Explosives Use			30		
3.9	GHG Emissions from Fugitive Emissions of Sulfur Hexafluoride and Perfluorocarbons			31		
3.10	Fugitive (	GHG Emissio	ons from Refrigeration or Air Conditioning Equipment Use	32		
3.11	Deforesta	ation		33		
	3.11.1	GHG Emis	ssions from Forest Land Carbon Stock Loss	34		
	3.11.2	Loss of Ca	arbon Sequestration Capacity due to Deforestation	34		
3.12	Forests a	nd Their Rol	le in Climate Change Mitigation	35		
3.13	Loss of w	vetlands		37		
3.14	Wetland	Conservation	٦	40		
3.15	GHG Em	issions from	Ecosystem Eloodina			
0110	3.15.1	CO <sub>2</sub> Emis	sions from Ecosystem Flooding	41		
	3.15.2	CH₄ Emiss	sions from Ecosystem Flooding	43		
	3.15.3	N <sub>2</sub> O emiss	sions from flooded ecosystems	44		
3.16	GHG Em	issions from	Livestock and Agricultural Projects	45		
	3.16.1	3.16.1 Calculations with the Holos Software				
	3.16.2	Calculatio	n Using Equations (without the Holos software)	45		
		3.16.2.1	CH <sub>4</sub> Emissions from Enteric Fermentation	45		
		3.16.2.2	CH4 Emissions from Manure Storage and Processing	47		
		3.16.2.3	N <sub>2</sub> O Emissions from Manure Storage and Processing	48		
		3.16.2.4	N <sub>2</sub> O Emissions from Manure Application	49		
		3.10.2.3	Application and Crop Residue Application	r 50		
3.17	CH₄ Emis	ssions from L	andfill	51		
	3.17.1	LandGEM	I Calculation	51		
	3.17.2	Calculatio	n Without the LandGEM Model	52		
	3.17.3	Biogas Up	ograding and Calculation of Associated GHG Reductions	56		
3.18	GHG Em	issions from	Energy Use in Biogas Cleaning Operations	56		
3.19	CH₄ Emis	ssions from E	Biogas Destruction	56		
3.20	Fugitive (	CH₄ Emissior	ns from Biomethanization of Organic Waste	57		
3.21	GHG Emissions from Biogas Compression and Liquefaction5					
3.22	CH₄ and	N2O Emissio	ons from Organic Waste Composting	57		
3.23	GHG Em	issions from	Waste Incineration or Thermal Treatment of Hazardous Materials or Contaminated Soil	l 59		
	3.23.1 Fossil-based CO <sub>2</sub> Emissions from Municipal Waste Incineration (Other than Sludge)					
	3.23.2	Fossil-bas Hazardou	ed CO <sub>2</sub> Emissions from Incineration or Thermal Treatment of Municipal, Industrial and s waste, Biomedical Waste, and Sewage Sludge	59		
	3.23.3	CH₄ Emiss Waste, Bio	sions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous omedical Waste, and Sewage Sludge	60		

	3.23.4	N <sub>2</sub> O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge Calculated from Emission Factors	62
	3.23.5	N <sub>2</sub> O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous	60
	2.02.6	waste, Biomedical Waste, and Sewage Sludge, based on Flue Gas concentration data	62
	3.23.0	Energy Recovery and Associated GHG Emissions Reduction	03
3.24	Emission	s from Wastewater Treatment and Discharge	63
	3.24.1	CH <sub>4</sub> emissions from wastewater treatment or discharge	63
	3.24.2	N <sub>2</sub> O Emissions from Wastewater Treatment or Discharge	65
3.25	Hydrocar	bon Exploration and Development	67
	3.25.1	Context in Quebec	67
	3.25.2	Description of the sequence of operations	68
	3.25.3	Equation-based GHG Emissions Calculations	70
	3.25.4	Calculation of GHG emissions based on Emission Rates	72
	3.25.5	Presentation of results	72
3.26	Direct GI	IG Emissions from Natural Gas Processing, Transportation and Distribution	72
3.27	Direct GI	HG Emissions from Liquid Hydrocarbons Transportation by Pipeline	73
3.28	Indirect L	Ipstream or Downstream Emissions Attributable to Certain Projects	74
	3.28.1	Upstream GHG Emissions from Hydrocarbon Pipeline Projects	74
		3.28.1.1 Methodology for Calculating Upstream Emissions Proposed by Environment and Clin	nate
		Change Canada (ECCC)	74
		3.28.1.2 Calculation Methodology based on the Estimated Intensity of GHG Emissions from Upstream Oil and Gas Operations	75
	3.28.2	Modal Shift in Passenger and Freight Transport and Reduction of Associated GHG Emissions	
	0.20.2	3.28.2.1 Modal Shift in Passenger Transport	75
		3.28.2.2 Indirect Emissions from Various Modes of Freight Transportation (truck, train, and shi	ip)77
	3.28.3	Indirect Emissions or Emission Reductions due to Traffic Flow and Road Congestion	78
		3.28.3.1 Indirect Emissions Associated with Urban Sprawl or Urban Densification	79
	3.28.4	Life Cycle Assessment	79
	3.28.5	Carbon Footprint of Fuels used in Canada	80
3.29	Emission	s from Black Carbon	82
	3.29.1	Black Carbon Emissions from Stationary Combustion Systems	86
		3.29.1.1 Tier 1 Calculation of Black Carbon Emissions from Stationary Combustion Systems	86
		3.29.1.2 Tier 2 Calculation of Black Carbon Emissions from Stationary Combustion Systems	88
		3.29.1.3 Estimating the Climate Impact of Black Carbon Emissions from Stationary Combustic	n sa
	3 20 2	Calculation of Plack Carbon Emissions from Mahila Combustion Systems	09 80
	J.29.2	3 29 2 1 Tier 1 Calculation of Black Carbon Emissions from On-road Mobile Sources	09 89
		3.29.2.2 Tier 1 Calculation of Black Carbon Emissions from Off-road Mobile Sources	90
		3.29.2.3 Calculation of Black Carbon Emissions from Locomotives	92
		3.29.2.4 Calculation of Black Carbon Emissions from Marine Vessels	93
		3.29.2.5 Calculation of Black Carbon Emissions from Aircraft	93
3.30	Emission	s from Activities not Presented in this Guide or Emerging Quantification Issues	94
MITIG	ATION ME	ASURES FOR GHG EMISSIONS REDUCTION	94
4.1	Types an	d Examples of GHG Emissions Reduction Measures	94

	4.2	Quantification of GHG Emissions Reduction from Mitigation Measures	96
	4.3	GHG Emissions Mitigation Plan	. 97
	4.4	GHG Emissions Monitoring Plan	. 98
	4.5	Avoided Emissions	. 98
5	MAIN F	REFERENCES	100
APPEN	DIX A -	- Checklist of GHG Emission Sources to Consider by Sector	101
APPEN	DIX B -	- ADDITIONAL INFORMATION ON HYDROCARBON EXPLORATION AND DEVELOPMENT PROJECTS 1	105
APPEN	DIX C -	- GHG EMISSIONS MONITORING PLAN	106
APPEN	DIX D -	- Complementary Information on Biogenic Emissions	108
APPEN	DIX E –	Complementary Information on Black Carbon	110

# **LIST OF FIGURES**

FIGURE 1. SIMPLIFIED DIAGRAM OF THE SCOPE OF THE GUIDE <sup>*</sup>	8
FIGURE 2. EXAMPLES OF EMISSION SOURCES FOR EACH PHASE OF AN ACTIVITY	11
FIGURE 3. FORESTS AND THEIR ROLE IN CLIMATE CHANGE	36
FIGURE 4. SIMPLIFIED DIAGRAM OF LIFE CYCLE ASSESSMENT STEPS	80
FIGURE 5. LIFE CYCLE STEPS CONSIDERED FOR FUELS CI CALCULATIONS	81
FIGURE 6. EXAMPLE OF AN OPERATIONAL SEQUENCE FOR A TYPICAL HYDROCARBON PRODUCTION PROJECT	105

# **LIST OF TABLES**

TABLE 1. EXAMPLES OF GHG EMISSIONS ASSOCIATED WITH DIFFERENT ACTIVITIES	11
TABLE 2. STEPS IN THE GHG EMISSIONS QUANTIFICATION APPROACH	12
TABLE 3. GLOBAL WARMING POTENTIAL OF DIFFERENT GHGS (5 <sup>™</sup> IPCC REPORT)	15
TABLE 4. EXAMPLES OF GHG EMISSION INTENSITY UNITS BY PROJECT TYPE	16
TABLE 5. GHG EMISSION FACTORS OF FUELS	17
TABLE 6. EMISSION FACTORS FOR ENERGY MOBILE COMBUSTION SOURCES	19
TABLE 7. EMISSION FACTORS FOR BIOFUELS	20
TABLE 8. PROTOCOLS FOR QUANTIFYING GHG EMISSIONS FROM SOME INDUSTRIAL SECTORS COVERED BY THE RMRCECA	21
TABLE 9. CO2 EMISSION FACTORS FOR MINERAL PRODUCTS	25
TABLE 10. CO2 EMISSION FACTORS FOR THE IRON AND STEEL INDUSTRY	26
TABLE 11. CARBON CONTENTS FOR THE IRON AND STEEL INDUSTRY	26
TABLE 12. EMISSION FACTORS FOR ALUMINIUM PRODUCTION	26
TABLE 13. GHG EMISSION FACTORS BY TYPE OF PROCESS OF HYDROGEN PRODUCTION	27
TABLE 14. EMISSION FACTORS FOR CHEMICAL PRODUCTS PRODUCTION	29
TABLE 15. CO <sub>2</sub> Emission Factors for Selected Explosives	30
TABLE 16. REFRIGERATION AND AIR CONDITIONING SYSTEM LOADS AND EMISSION FACTORS	33
TABLE 17. EQUATION 10 PARAMETERS FOR DETERMINING $CO_2$ EMISSIONS FROM DEFORESTATION ACTIVITIES	34
TABLE 18. EQUATION 11 PARAMETERS FOR DETERMINING $CO_2$ EMISSIONS FROM DEFORESTATION ACTIVITIES	35
TABLE 19. AVERAGE CARBON STOCK FOR EACH TYPE OF WETLAND IN EASTERN CANADA	39
TABLE 20. DEFAULT BASELINE VALUES ASSOCIATED WITH SOIL ORGANIC CARBON STOCKS (COSREF) UNDER NATURAL VEGETATION	42
TABLE 21 AVERAGE CH <sub>4</sub> Emission Factors of Reservoirs	44
TABLE 22. AVERAGE $N_2O$ Emission Factors for Reservoirs	44
TABLE 23. CH4 EMISSION FACTORS ASSOCIATED WITH ENTERIC FERMENTATION	46
TABLE 24. CH <sub>4</sub> Emission Factors Associated with Manure Storage and Processing	47
TABLE 25. ANNUAL NITROGEN EXCRETION RATE FROM MANURE	49
TABLE 26. N <sub>2</sub> O Emission Factors by Manure Management Approach	49
TABLE 27. NITROGEN CONTENT OF DIFFERENT TYPES OF MANURE AND SLURRY	50
TABLE 28. ANNUAL N2O EMISSION FACTOR PER TONNE OF NITROGEN FROM FERTILIZER AND CROP RESIDUE APPLICATION	51
TABLE 29. PARAMETERS OF THE FIRST-ORDER DECOMPOSITION MODEL FOR LANDFILL WASTE	54
TABLE 30. DOC, DOCF AND K PARAMETERS BY TYPE OF WASTE	55
TABLE 31. DOC x DOCF PARAMETERS ACCORDING TO SECTORS AND SLUDGE	55
TABLE 32. PARAMETER K ACCORDING TO SECTORS AND SLUDGE	55
TABLE 33. BIOGAS DESTRUCTION EFFICIENCY	56
TABLE 34. CH <sub>4</sub> and $N_2O$ Emission Factors Associated with OWM Composting	58
TABLE 35. DEFAULT FACTORS FOR THE CALCULATION OF $CO_2$ EMISSIONS	60
Table 36. Default $CH_4$ and $N_2O$ Emission Factors for Incineration Facilities	61
TABLE 37. METHANE EMISSION FACTORS ASSOCIATED WITH DIFFERENT TYPES OF WASTEWATER TREATMENT	64

TABLE 38. N <sub>2</sub> O Emission Factors Associated with Different Types of Residential and Industrial Wastewater Treatme	NT.66
TABLE 39. FRACTION OF NITROGEN REMOVED DURING WASTEWATER TREATMENT (NREM)	67
TABLE 40. GHG EMISSION SOURCES AND REFERENCES FOR QUANTIFICATION	70
TABLE 41. GHG EMISSION FACTORS ASSOCIATED WITH DIFFERENT MODES OF FREIGHT TRANSPORT, IN KILOGRAMS OF CO2 EQUIVA	ALENT
per Tonne Transported per Kilometre	78
TABLE 42. CARBON INTENSITY (CI) OF FUELS PRODUCED OR DISTRIBUTED IN CANADA.	81
TABLE 43. CANADIAN BLACK CARBON EMISSIONS IN 2022	83
TABLE 44. BLACK CARBON EMISSIONS IN QUEBEC, IN 2022	84
TABLE 45. EMISSION FACTORS (EF <sub>1,1,PM2.5</sub> ), TIER 1	87
TABLE 46. SPECIATION FACTORS (SF), TIER 1	88
TABLE 47. ELEMENTAL CARBON EMISSION FACTORS FOR DIESEL AND GASOLINE	90
TABLE 48. PM <sub>10</sub> Emission Standards for Off-road Machinery	91
TABLE 49. PM <sub>2.5</sub> EMISSION FACTORS AND SPECIATION FACTORS ASSOCIATED WITH DIFFERENT FUEL TYPES USED IN MARINE VESSELS	93
TABLE 50. TYPES OF GHG EMISSIONS REDUCTION MEASURES (NON-EXHAUSTIVE LIST)	95
TABLE 51. EXAMPLE OF REDUCTION CALCULATION FOR STATIONARY COMBUSTION SOURCES	97
TABLE 52. EXAMPLE OF REDUCTION CALCULATION FOR MOBILE COMBUSTION SOURCES	97
TABLE 53. CHECKLIST OF GHG EMISSION SOURCES TO CONSIDER BY SECTOR	101
TABLE 54. EXAMPLES OF DATA TO BE INCLUDED IN A GHG EMISSIONS MONITORING PLAN (NON-EXHAUSTIVE)	106
TABLE 55. GLOBAL WARMING POTENTIAL OF BLACK CARBON OVER PERIODS OF 20, 100 AND 500 YEARS	110

# LIST OF EQUATIONS

EQUATION 1: GHG EMISSIONS INTENSITY	16
EQUATION 2: GHG EMISSIONS FROM STATIONARY COMBUSTION SOURCES	17
EQUATION 3: GHG EMISSIONS FROM THE USE OF MOBILE EQUIPMENT	18
EQUATION 4: GHG EMISSIONS FROM HYDROGEN USE	27
EQUATION 5: GHG EMISSIONS FROM THE USE OF EXPLOSIVES	30
EQUATION 6: GHG EMISSIONS FROM EXPLOSIVES USE	30
EQUATION 7: ESTIMATED GHG EMISSIONS FROM SF <sub>6</sub> -CONTAINING EQUIPMENT USED IN ELECTRICITY TRANSMISSION AND DI	STRIBUTION
	31
EQUATION 8: ESTIMATED GHG EMISSIONS FROM PFC-CONTAINING EQUIPMENT USED IN ELECTRICITY TRANSMISSION AND D	ISTRIBUTION
	32
EQUATION 9: GHG EMISSIONS FROM REFRIGERATION AND AIR CONDITIONING EQUIPMENT USE	32
EQUATION 10: CO2 EMISSIONS FROM THE LOSS OF FOREST LAND CARBON STOCKS.	34
EQUATION 11: NET LOSS OF CO <sub>2</sub> SEQUESTRATION FOR A DETERMINED NUMBER OF YEARS	35
EQUATION 12: CO <sub>2</sub> Emissions from Wetland Loss	38
EQUATION 13: CHANGE IN CARBON STOCKS OF LIVING BIOMASS FROM LAND CONVERTED TO FLOODED LAND	41
EQUATION 14: LIVING BIOMASS BEFORE CONVERSION OF FOREST LAND TO FLOODED LAND	42
EQUATION 15: CO <sub>2</sub> Emissions from Forest Land Flooding	42
EQUATION 16: CO2 EMISSIONS FROM WILDLANDS FLOODING	43
EQUATION 17: CH4 EMISSIONS FROM ECOSYSTEM FLOODING	43
EQUATION 18: N2O EMISSIONS FROM ECOSYSTEM FLOODING	44
EQUATION 19: METHANE EMISSIONS FROM ENTERIC FERMENTATION	46
EQUATION 20: CH <sub>4</sub> Emissions from Manure Storage and Processing	47
EQUATION 21: N2O EMISSIONS FROM MANURE STORAGE AND PROCESSING	48
EQUATION 22: N <sub>2</sub> O Emissions from Manure Application	49
EQUATION 23: N <sub>2</sub> O Emissions from Inorganic and Organic Fertilizers and Crop Residues Application	50
EQUATION 24: CH4 EMISSIONS FROM WASTE LANDFILLED	52

EQUATION 25: CALCULATION OF DEGRADABLE AND DECOMPOSABLE ORGANIC CARBON (DDOCM)	53
EQUATION 26: CALCULATION OF ACCUMULATED DDOCM	53
EQUATION 27: CALCULATION OF DECOMPOSED DDOCM	53
EQUATION 28: CH <sub>4</sub> Emissions from Landfilled Waste as a Function of Degradable and Decomposable Organic Ca	RBON 54
EQUATION 29: METHANE EMISSIONS FROM BIOGAS COMBUSTION	56
EQUATION 30: FUGITIVE METHANE EMISSIONS FROM BIOGAS PROCESSING	57
EQUATION 31: METHANE EMISSIONS FROM WASTE COMPOSTING	58
Equation 32: $N_2O$ Emissions from Waste Composting	58
EQUATION 33: NON-BIOGENIC CO <sub>2</sub> EMISSIONS FROM MUNICIPAL WASTE INCINERATION, OTHER THAN SLUDGE	59
EQUATION 34: NON-BIOGENIC CO2 EMISSIONS FROM INCINERATION OR THERMAL TREATMENT OF MUNICIPAL, INDUSTRIAL AND	1D
HAZARDOUS WASTE, BIOMEDICAL WASTE, AND SEWAGE SLUDGE	60
EQUATION 35: CH <sub>4</sub> Emissions from Incineration or Thermal Treatment of Waste	61
EQUATION 36: N <sub>2</sub> O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous	Waste,
BIOMEDICAL WASTE, AND SEWAGE SLUDGE CALCULATED FROM EMISSION FACTORS	62
EQUATION 37: N <sub>2</sub> O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous	Waste,
BIOMEDICAL WASTE, AND SEWAGE SLUDGE, BASED ON FLUE GAS CONCENTRATION DATA	63
EQUATION 38: CH4 EMISSIONS FROM WASTEWATER TREATMENT OR DISCHARGE	63
EQUATION 39: CALCULATION OF ANNUAL ORGANIC LOAD	64
EQUATION 40: N <sub>2</sub> O Emissions from Wastewater Treatment or Discharge	65
EQUATION 41: TOTAL NITROGEN IN MUNICIPAL WASTEWATER	66
EQUATION 42: TOTAL AMOUNT OF NITROGEN PRESENT IN INDUSTRIAL WASTEWATER	67
EQUATION 43: TOTAL AMOUNT OF NITROGEN SENT TO EFFLUENT	67
EQUATION 44: GHG EMISSIONS FROM PROJECT IMPACTS ON MODAL SHIFT	76
EQUATION 45: INDIRECT EMISSIONS FROM PROJECT IMPACTS ON FREIGHT TRANSPORTATION	77
EQUATION 46: BLACK CARBON EMISSIONS FROM STATIONARY COMBUSTION SOURCES (TIER 1)	86
EQUATION 47: BLACK CARBON EMISSIONS FROM STATIONARY COMBUSTION SOURCES (TIER 2)	88
EQUATION 48: BLACK CARBON EMISSIONS FROM STATIONARY COMBUSTION SOURCES (TIER 2)	89
EQUATION 49: BLACK CARBON EMISSIONS FROM ON-ROAD MOBILE SOURCES (TIER 1)	90
EQUATION 50: ANNUAL BLACK CARBON EMISSIONS FROM OFF-ROAD MOBILE SOURCES (TIER 1)	90
EQUATION 51: ANNUAL BLACK CARBON EMISSIONS FROM LOCOMOTIVES (TIER 1)	92
EQUATION 52: ANNUAL BLACK CARBON EMISSIONS FROM MARINE VESSELS (TIER 1)	93
EQUATION 53: ANNUAL BLACK CARBON EMISSIONS FROM AIRCRAFT	94

# **TERMS AND DEFINITIONS**

#### **IMPORTANT NOTE**

The definitions presented in this guide are based on the definitions provided by climate change expert organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the World Resources Institute (WRI). However, if a project is subject to a Quebec regulation on greenhouse gases (GHGs), the definitions in that regulation take precedence.

#### Agricultural biomass

Organic matter produced by energy crops (e.g. switchgrass, reed canary grass, miscanthus), crop residues (e.g. cereal straw, corn stalks, oat hulls, flax residues) or animal waste.

#### Anthropogenic GHG emissions

GHG emissions resulting from human activity.

#### Avoided GHG emissions

Emission reductions achieved by a company or an organization's activities, products, and/or services, when these reductions occur outside its scope of activity. They must be assessed against a baseline scenario.

#### **Biogenic GHG emissions**

GHG emissions produced from biomass sources.

#### Biofuel

Any fuel whose energy-generating capacity is entirely derived from biomass.

#### Biomass

All organic matter that can become a source of energy. Organic matter includes both plant matter (food waste, wood, leaves, etc.) and animal matter (dead animals and living organisms in the soil).

#### **Black carbon**

Aerosol (airborne particles) emitted during the combustion process. Black carbon is not emitted alone; it is a component of particulate matter with a diameter of 2.5 microns or less (PM<sub>2.5</sub>).

#### Carbon debt

Time required for a biomass energy project to become more attractive in terms of GHG emissions than the use of the fossil fuel it replaces. The time required is accumulated annually as a carbon debt. Benefits in terms of CO<sub>2</sub> emissions reduction only appear when this debt is eliminated, which can take from a few years to several decades, depending on the project parameters.

#### **Carbon neutral**

That has a neutral balance in terms of GHG emissions.

#### **Crop residues**

Plant residues from agriculture consisting of parts of plant matter that is left on the field where it decomposes (e.g., cereal straws, corn stalks, or third-grade hay).

#### **Direct GHG emissions**

GHG emissions whose source is controlled by the project owner.

#### Fossil fuel

Non-renewable solid, liquid, or gaseous fuel coming from the transformation of vegetable and animal mass after a very long geological process called "methanization" which produces compounds of more or less long carbon chains.

#### Greenhouse gas (GHG)

Natural or anthropogenic gaseous atmospheric constituent that absorbs and emits infrared radiation in the wavelength emitted by the surface of the earth, the atmosphere, and clouds.

#### **GHG** source

Any process, activity, or mechanism that releases a greenhouse gas, aerosol, or the precursor of a greenhouse gas or aerosol into the atmosphere.

#### GHG emissions from combustion

GHG emissions related to the exothermic reaction of a fuel.

#### GHG emission or removal factor

Factor used to convert activity data into GHG emissions or reductions.

#### GHG emissions from industrial processes

Emissions from certain industrial processes that produce GHGs directly and whose primary purpose is not to provide energy. This category of GHG emissions includes emissions resulting from chemical reactions produced during a specific process (e.g., CO<sub>2</sub> from the calcination of limestone), emissions generated by the use of fossil fuels as raw materials or chemical reagents (e.g., metallurgical coke used as a reducing agent), and resulting from the direct emission of certain GHGs (e.g., SF<sub>6</sub> used in a variety of industrial processes or specific installation systems, or HFC emissions from industrial refrigeration systems).

#### **GHG** reservoir

A component of the climate system, other than the atmosphere, capable of storing, accumulating, or emitting a substance of concern (e.g., carbon, a greenhouse gas, or a precursor). Examples of carbon reservoirs include oceans, soils, and forests.

#### **GHG** removal

Removal of a GHG from the atmosphere by GHG sinks.

#### GHG sink

Any process, activity, or mechanism that removes a greenhouse gas, aerosol, or precursor to a greenhouse gas or aerosol from the atmosphere.

#### Global warming potential (GWP)

Relative measure of the warming effect that the emission of one kilogram of a GHG has at the tropospheric surface compared to the warming effect of the emission of one kilogram of CO<sub>2</sub>.

#### Indirect GHG emissions

GHG emissions that are a consequence of project activities, but whose sources are controlled by other entities.

#### ISO 14164

International standard published by the International Organization for Standardization (ISO) that specifies the principles and requirements applicable at the organization level for quantifying and reporting GHG emissions and removals. It includes requirements regarding the design, development, management, reporting, and verification of GHG inventories.

#### Land use, land-use change, and forestry (LULUCF)

Impact category used in GHG emissions inventories that covers GHG emissions and removals resulting directly from human activity related to land use, land-use change, and forestry, excluding agriculture, whose emissions are accounted for elsewhere.

#### Lignocellulosic crops

Cultivation of perennial herbaceous plants for energy production on marginal agricultural land (miscanthus, reed canary grass, switchgrass, etc.).

#### Other GHG emissions

GHG emissions other than those from combustion and industrial processes.

#### Process

Any method, reaction or operation by which processed materials undergo a physical or chemical change in a single production line. Processes are also defined as all successive operations performed on the same material and resulting in the same kind of physical change.

#### **Radiative forcing**

Radiative forcing is a measure of a gas's ability to reflect infrared light radiation. It is measured in watts per square metre (W/m<sup>2</sup>).

#### **Residual biomass**

Organic matter of plant or animal origin, essentially from agricultural, forest, industrial, or urban sources.

#### **Residual forest biomass**

Forest biomass resulting from harvesting activities (slash [branches and tops], non-commercial tree parts, twigs, and foliage), primary or secondary processing activities (bark, shavings, sawdust, and chips), as well as sludge, pulp liquor, pellets, and compressed wood logs. Residual forest biomass also includes unadulterated, uncontaminated deconstruction wood when not used in a 3R-RD (reduction, reuse, recycling, reclamation, and disposal) waste management hierarchy. Standing trees are not considered as residual forest biomass.

#### Woody crops

Trees grown on marginal agricultural land for combustion (fast-growing willow, hybrid poplar, etc.) and whose method of cultivation is more akin to agriculture than forestry.

# **ACRONYMS AND ABBREVIATIONS**

- API American Petroleum Institute
- CH<sub>4</sub> Methane
- CO<sub>2</sub> Carbon dioxide
- ECCC Environment and Climate Change Canada
- CO<sub>2</sub> eq. Carbon dioxide equivalent
- g CH<sub>4</sub> Gram of methane
- g CO<sub>2</sub> Gram of carbon dioxide
- g CO2 eq. Gram of carbon dioxide equivalent
- GHG Greenhouse gas
- IPCC Intergovernmental Panel on Climate Change
- GJ Gigajoule
- g N<sub>2</sub>O Gram of nitrous oxide
- LNG Liquefied natural gas
- HFC Hydrofluorocarbons
- HFO Hydrofluoroolefins
- kg CH<sub>4</sub> Kilogram of methane
- kg CO2 eq. Kilogram of carbon dioxide equivalent
- kg N<sub>2</sub>O Kilogram of nitrous oxide
- kWh Kilowatt-hour
- EQA Environment Quality Act
- MELCCFP Ministère de l'Environnement et de la Lutte contre les changements climatiques, de la Faune et des Parcs (Quebec Ministry of Environment, Climate Change, Wildlife and Parks)
- MJ Megajoule
- N<sub>2</sub>O Nitrous oxide
- NF<sub>3</sub> Nitrogen trifluoride
- LHV Lower heating value
- HHV Higher heating value

EIARP	Environmental impact assessment and review procedure			
PFC	Perfluorocarbons			
GWP	Global warming potential			
RMRCECA	Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere			
NIR	National Inventory Report			
RREIAR	Regulation respecting the environmental impact assessment and review of certain projects			
SF <sub>6</sub>	Sulfur hexafluoride			
CATS	Quebec cap-and-trade system for greenhouse gas emission allowances			
SSR	Greenhouse gas source, sink, and reservoir			
t CO <sub>2</sub> eq.	Tonne of carbon dioxide equivalent			
t CO <sub>2</sub> eq./y	Tonnes of carbon dioxide equivalent per year			
tkm	Tonne-kilometre of transportation			
US EPA	United States Environmental Protection Agency			
LULUCF	Land use, land-use change, and forestry			
WRI	World Resources Institute			

# **INTRODUCTION**

The purpose of this guide is to present the methodologies applicable to greenhouse gas (GHG) emissions quantification in sectors affected by climate change, particularly before an activity is carried out (see the cautionary note below). It is based on extensive research into methodologies developed by recognized organizations in the field, including the Intergovernmental Panel on Climate Change (IPCC)<sup>1</sup> and Environment and Climate Change Canada (ECCC). Currently, quantifiers must consult several references on websites of various organizations. This guide is therefore a first in Quebec, since it brings together in a single document the methods and references to support clients in their quantification work. It is expected that this guide will be updated periodically to reflect the changes made to the methodologies by the responsible organizations.

Many clients, including businesses, consultants, government and municipal stakeholders, as well as professionals, may need to quantify GHG emissions attributable to an activity.

The purpose of this guide is to provide a methodology for:

- GHG emissions reduction programs (e.g., design and implementation of a climate change action plan)
- Grant applications (e.g., municipal or provincial programs, federal agreements)
- GHG emissions reporting, validation, and verification
- GHG emissions reduction measures

This guide provides:

- General information on greenhouse gases
- The general approach to assessing GHG emissions
- The main sources of GHG emissions
- Calculation formulas and methodologies for quantifying GHG emissions
- Some mitigation measures and guidelines for monitoring and tracking GHG emissions

**<u>Reader's note:</u>** In the application of the Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (RMRCECA) and the Regulation respecting a cap-and-trade system for greenhouse gas emission allowances (RCATS), the regulated methods take precedence. Both regulations govern a certain number of emitters based on specified emission thresholds and apply during the operational phase of projects. The threshold for the RMRCECA is 10,000 tonnes of CO<sub>2</sub> equivalent per year for the covered clienteles, and the CATS threshold is 25,000 tonnes of CO<sub>2</sub> equivalent per year for the covered facilities and clienteles. The Figure 1 presents a simplified diagram of the scope of this guide.

<sup>1</sup> IPCC 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol1.html

Figure 1. Simplified Diagram of the scope of the guide\*



\*This diagram is not restrictive. Please refer to regulations for specific requirements.

# **GENERAL CONCEPTS**

# 1.1 GHG to Consider

The GHGs that must be considered in the emissions assessment are those used by the RMRCECA, namely:

- Carbon dioxide (CO<sub>2</sub>)
- Methane (CH<sub>4</sub>)
- Nitrous oxide (N<sub>2</sub>O)
- Sulphur hexafluoride (SF<sub>6</sub>)
- Nitrogen trifluoride (NF<sub>3</sub>)
- The family of hydrofluorocarbons (HFCs)
- The family of perfluorocarbons (PFCs)

# 1.2 Direct and Indirect GHG Emissions

#### 1.2.1 Direct GHG Emissions

These are emissions from sources that are attributable to, or controlled by, the issuer or project owner. They also include emissions from its subcontractors.

#### 1.2.2 Indirect GHG Emissions from Electricity Consumption

These are indirect emissions related to the third-party generation of electricity that is purchased and consumed by the project owner. It should be noted that due to Quebec's energy portfolio, which is largely

hydroelectric, these emissions are generally very low. However, in some regions of Quebec not supplied by the electrical grid, they can be significant when fossil fuels are used to produce electricity.

#### 1.2.3 Upstream, Downstream or Life-cycle Indirect GHG Emissions

Indirect GHG emissions include all other emissions that are beyond the direct control of the issuer or project owner. Several terms are used to refer to indirect emissions: "upstream", "downstream", or "life cycle".

#### Definition of "upstream":

The term "upstream" refers to all industrial activities, from resource extraction to project completion. Upstream activities will vary depending on the resource and type of project, but in general, they include the extraction, processing, handling, and transportation of the necessary inputs. As an example, a hydrocarbon pipeline project may include the following upstream activities:

- Extraction: crude oil and gas well development, oil and gas field development, and in situ development
- Processing: on-site processing and upgrading
- Handling: transfer of products to terminals
- Transportation: pre-project pipeline transportation and operation.

#### Definition of "downstream":

Downstream emissions are associated with subsequent activities resulting from the project. For example, GHG emissions associated with the flow of road traffic resulting from a road construction project are indirect downstream emissions.

#### Life cycle definition:

The life cycle approach aims to consider the impacts (environmental, social, and economic) specific to a product or service, from resource acquisition to end of life. The boundaries of the life cycle assessment can vary, with some extending from "cradle to grave," "well to wheel," or "well to refinery gate." See Figure 5.

### **1.3 GHG Emission Sources**

**Reader's note:** For simplicity and to cover as many scenarios as possible, this guide is based on the definitions of emission sources proposed by the IPCC and WRI. However, if a project is subject to GHG regulations in Quebec, the definitions presented in the regulations take precedence.

#### 1.3.1 Combustion GHG Emissions

Combustion GHG emissions are caused by an exothermic reaction when fuel is burned. Combustion emissions can be from a stationary source (e.g., a boiler for heating) or a mobile source (e.g., a truck for transporting materials).

#### 1.3.2 GHG Emissions from Industrial Processes

This category includes emissions from the non-energy use of fuels as well as GHGs emitted as a direct byproduct of industrial processes. It includes emissions involving chemical reactions other than combustion and whose primary purpose is not energy production. For example, GHG emissions from industrial processes may be generated in the manufacture of several products such as cement, iron, steel, aluminium, or nitric acid.

This category also includes GHG emissions from various purposes such as refrigeration and plastic foam manufacturing, as well as GHG emissions from the use of solvents, propellants, and anesthetics.

Where industrial process emissions are produced together with emissions from fuel burned for energy purposes, they should be separated and categorized accordingly.

#### 1.3.3 Other GHG Emissions

Other GHG emissions include all emissions that are not attributable to combustion or industrial processes. Examples include:

- Fugitive methane emissions from the decomposition of organic materials in a landfill
- Methane emissions from enteric fermentation in ruminants
- Nitrous oxide (N<sub>2</sub>O) emissions from fertilizer application
- CH<sub>4</sub> or N<sub>2</sub>O emissions from wastewater treatment
- Emissions from the use of explosives in mining or road projects, for example
- Losses of carbon reservoirs due to deforestation or land-use change.

#### 1.3.4 The Specific Case of Biogenic CO<sub>2</sub> Emissions

CO<sub>2</sub> emissions from biomass are called "biogenic emissions". They are associated with the short carbon cycle, the decomposition or the combustion of organic matter in the presence of oxygen. These emissions are considered carbon neutral and must be considered separately from non-biogenic GHG emissions. It should be noted, however, that CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass are not carbon neutral. Some examples of carbon-neutral fuels are waste biomass, biogas, wood pellets, mixed liquor, ethanol, and biodiesel. These emissions should be presented separately in the quantification results. Appendix D provides more details on biogenic emissions.

### 1.3.5 Examples of Emission Sources by Implementation Phase

Figure 2 presents examples of emission sources for different project phases.

Construction (C)	Operation (O)	Closure, post-closure (CL)
Stationary combustion sources (e.g. generators)	Stationary combustion sources (e.g. boilers)	Stationary combustion sources (e.g. generators)
Mobile combustion sources (e.g. transportation, machinery)	Mobile combustion sources (e.g.: same as previous)	Mobile combustion sources (e.g. same as previous)
Explosives (e.g. roads, mines)	Industrial processes, refrigeration	Fugitive emissions
Deforestation (e.g. landfills, mines, biofuels,	Electrical power	
road construction, etc.)	Fugitive emissions (e.g. SF <sub>6</sub> , CH <sub>4</sub> )	
Flooding of ecosystems (e.g. dams, dykes)		

		-			-
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FIGURE /	Framnies		Sources for	Each Phase	of an Activity
	LAUNDICO				

### 1.3.6 Examples of Emission Sources Associated with Different GHGs

Table 1 provides a non-exhaustive list of examples of emission sources associated with different GHGs.

Table 1. Examples of GHG Emissions Associated with Different Activities				
GHG	Main Sources (Non-exhaustive List)			
Carbon dioxide (CO <sub>2</sub> )	<ul><li>Fuel combustion</li><li>Industrial processes</li><li>Deforestation</li></ul>			
Methane (CH <sub>4</sub> )	<ul> <li>Landfill sites</li> <li>Oil and gas projects</li> <li>Livestock rearing</li> </ul>			
Nitrous oxide (N <sub>2</sub> O)	Agricultural projects			
Sulfur hexafluoride (SF <sub>6</sub> )	<ul> <li>Electricity generation and transmission</li> <li>Electronic component manufacturing</li> <li>Magnesium production</li> </ul>			
Nitrogen trifluoride (NF3)	Semiconductor, solar panel, flat-panel TV and touch screen manufacturing			
Hydrofluorocarbon (HFC) and perfluorocarbon (PFC) families	<ul> <li>Refrigeration and air conditioning equipment</li> <li>Aluminium production</li> </ul>			

#### 1.3.7 Exclusions

All sources that cumulatively account for less than 3% of the total GHG emissions generated by the project can therefore be considered insignificant and may be excluded. The exclusion must be justified by a summary quantification based on credible and verifiable assumptions, a comparison with a similar project, or any other approach that demonstrates that the emissions are less than 3%.

### **1.4 Quantification Approach**

This guide proposes five main steps to facilitate the quantification of GHG emissions:

- 1. Identify the sources of GHG emissions
- 2. Consider whether specific regulatory requirements apply to GHG emissions
- 3. Quantify the impacts of GHG emissions
- 4. Develop an impact mitigation plan
- 5. Develop a GHG emissions monitoring and tracking plan.

	Table 2. Steps in the GHG Em	issions Quantification Approach
	Action	Observations
1.	Identify GHG emission sources	
	- Identify all sources of GHG emissions related to the activity, project, or action	All sources for all phases must be identified.
	<ul> <li>Identify the impacts of the activity, project, or action on carbon sinks and reservoirs</li> </ul>	Carbon sinks and reservoirs (forests, wetlands, geological formations, etc.) play an important role in climate change and should not be overlooked in the quantification of GHG emissions.
2.	Consider whether specific regulatory requirements apply to GHG emissions	The RMRCECA, RCATS, and Regulation respecting halocarbons are examples of regulations that address GHG emissions.
3.	Quantify the impacts of the activity, project, or action on GHG emissions	
	- Quantify overall GHG emissions	Determine the GHG emissions generated at all phases of the activity, project, or measure, using recognized quantification sources and reliable, verifiable assumptions. This guide provides quantification methodologies.
	<ul> <li>Quantify the impacts of the activity, project, or measure on the increase or reduction of carbon sinks and reservoirs</li> </ul>	Examples of a potential impact on carbon sinks and reservoirs: loss of carbon stock due to deforestation activities, CO <sub>2</sub> capture and sequestration due to reforestation activities.
	- Comply with GHG quantification principles	<ul> <li>Relevance: Consider only the sources from which GHG emissions can be quantified.</li> <li>Completeness: Include all relevant data. When a GHG emission source is excluded, a justification must be provided for this choice.</li> <li>Consistency: Use a consistent, accurate, and appropriate calculation methodology.</li> </ul>

Table 2. Steps in the GHG Emissions Quantification Approach			
Action	Observations		
	Accuracy: Limit uncertainties. Transparency: Provide access to data, sources, references, and calculation methodologies used. Project documentation should include sufficient references to data sources and methodology (especially if different from this guide). Caution: Use reasonable assumptions, data, and methodologies so as not to underestimate GHG emissions.		
4. Develop a GHG mitigation plan	The purpose of the mitigation plan is to develop ways to reduce the GHG emission impacts of the activity, project, or measure. The GHG reductions from the mitigation measures must be quantified. Section 4 of this guide provides more detail on the development of the mitigation plan.		
5. Develop a GHG emissions monitoring plan	The monitoring plan is used to track GHG emissions and observe the effectiveness of mitigation measures over time. Typically, a monitoring plan will specify the types of data to be collected (e.g., equipment fuel consumption), the process and methods used to collect the data, the frequency of data collection, and the annual results. Section 4 of this guide provides more detail on this topic.		

### **1.5 Quantification Reports**

Any quantification report must be filed by a person competent in the field of GHG emissions quantification (see next section for details). At a minimum, the five steps of the general quantification approach outlined above should form the basis of any quantification report. The following are examples of quantification report content.

### 1.5.1 To Assess the Impacts of GHG Emissions from an Activity or Project

At a minimum, the report should present:

- The steps in the overall quantification approach
- The quantification methodologies used
- The annual GHG emissions from all project emission sources (see section on reporting)
- The mitigation measures and resulting GHG emission reductions
- How the mitigation measures are being implemented
- The emissions monitoring plan
- The qualifications of the person or organization performing the quantification.

For hydrocarbon exploration and development projects (Section 1.33), this guide outlines specific requirements that must be included in the quantification report.

### 1.5.2 For GHG Emissions Reduction Projects

The quantification report can be based on the GHG Report Template for the GHG CleanProjects© Registry published online by the CSA<sup>™2</sup> Group. At a minimum, the report must include the following information:

- The project description (project scenario)
- The baseline scenario and a justification for its choice
- The inventory of sources, sinks and reservoirs for the project and the baseline scenario
- The quantification and calculation of GHG emissions
- A summary of the environmental impact analyses
- Details on the data and information management system monitoring and data control mechanisms
- Details pertaining to reporting and verification
- Any aspects related to a potential program to which the emissions reduction project is linked
- The qualifications of the person performing the quantification or a presentation of the quantifying organization
- Any other relevant aspect.

Please note that this list is for guidance only and that, if so, any program criteria take precedence over this list.

# 1.6 Competent Person for GHG Emissions Quantification

A "competent quantifier" is an individual or company that can demonstrate competence in quantifying GHG emissions and who, at a minimum:

 has completed training in one of the three parts of ISO 14064<sup>3</sup> relating to greenhouse gases, performed quantifications as part of his or her duties, and can provide evidence of this.

OR

 is accredited to ISO 14064 for validation and verification of gases, has performed quantifications as part of their duties, and can provide proof of this (e.g., certification or proof of training on ISO 14064).

This person can be an internal or external resource of the organization. Accreditation is not mandatory but is desirable.

<sup>&</sup>lt;sup>2</sup> Home | CSA Group Registries (csaregistries.ca)

<sup>&</sup>lt;sup>3</sup> 14064-1: Key Principles of Greenhouse Gas Inventories for Organizations

<sup>14064-2:</sup> Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements

<sup>14064-3:</sup> Specification with guidance for the validation and verification of greenhouse gas assertions

# **1.7 Presentation of Results and Global Warming Potentials**

Results should be presented as follows:

- In metric units, in accordance with IPCC principles and international conventions
- On an annual basis per calendar year
- Based on the number of years of emissions during the construction and closure or post-closure phases, if applicable
- Individually by GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, SF<sub>6</sub>, etc.)
- Summed up for all GHGs and expressed in tonnes of carbon dioxide equivalent (t CO<sub>2</sub> eq.). Carbon dioxide equivalent is calculated by multiplying the mass of a given GHG by its global warming potential (GWP). Using the GWPs for quantifying GHG emissions that are presented in Table 3
- By distinguishing each of the applicable project phases (construction, operation, closure)
- By distinguishing the different applicable emission source categories (mobile combustion, stationary combustion, processes, and others)
- By distinguishing non-biogenic emissions from biogenic CO<sub>2</sub> emissions
- In emission intensity (carbon footprint) when useful or required in a project, or for comparison with other similar projects (e.g., total GHG emissions per unit of production for an industry, total GHG emissions per kilometre of road built, GHG emissions per passenger-year for public transportation).

Table 3. Global Warming Potential of Different GHGs (5th IPCC Report)					
Type of GHG	Quantity (metric tonnes)	Global warming potential (no units)	Carbon dioxide equivalent (t CO₂ eq.)		
Carbon dioxide (CO <sub>2</sub> ) Methane (CH <sub>4</sub> ) Nitrous oxide (N <sub>2</sub> O) Sulfur hexafluoride (SF <sub>6</sub> ) Nitrogen trifluoride (NF <sub>3</sub> ) Hydrofluorocarbons (HFC) Perfluorocarbons (PFC)	1 1 1 1 1 1	1 28 265 23,500 16,100 Can vary from 4 to almost 12,400 Can vary from 6,000 to almost 12,000	1 28 265 23,500 16,100 Variable, depending on the molecules considered <sup>4</sup> Variable, depending on the molecules considered		

A complete list of GWPs for each GHG can be found in Quebec's GHG inventory, updated annually by the MELCCFP and available at <u>www.environnement.gouv.qc.ca/changements/ges/index.htm</u>.

<sup>&</sup>lt;sup>4</sup> Environment and Climate Change Canada: https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gasemissions/quantification-guidance/global-warming-potentials.html

### **1.8 GHG Emissions Intensity**

GHG emissions intensity (EI) is an increasingly important piece of information in the field of climate change. For example, EI allows a comparison of the carbon footprint of one technology with another in order to make more informed choices in a GHG emissions mitigation approach. EI is relevant for many projects, especially in the industrial sector. The EI will be requested by the MELCCFP when relevant and must be calculated using the following equation:

**Equation 1: GHG Emissions Intensity** 

# $GHG \ emssions \ intensity = \frac{Net \ GHG \ emissions}{Units \ produced}$

The values for "net GHG emissions" and "units produced" in Equation 1 must correspond to emissions and production at the maximum capacity of the project.

Table 4. Examples of GHG Emission Intensity Units by Project Type		
Type of Project	GHG El Units	
Metal production	t CO <sub>2</sub> eq. / tonne of metal produced	
Power generation	t CO <sub>2</sub> eq. / GWh generated	
Oil production	t CO <sub>2</sub> eq. / barrel produced	
Polystyrene production	t CO <sub>2</sub> eq. / tonne of polystyrene produced	
Mineral extraction	t CO <sub>2</sub> eq. / tonne of ore	
Pipeline	t CO <sub>2</sub> eq. / barrel transported	
Gas pipeline	t CO <sub>2</sub> eq. / million cubic feet transported	

Table 4 provides some examples of EI units by project type.

For some types of projects, it may not be possible or appropriate to establish Els, in which case, it's determination will not be required.

# **Quantification of GHG Emissions**

This section presents the equations and calculation methods to be applied when assessing GHG emissions from different emission sources. They are particularly relevant before an activity is carried out in the absence of actual data. The checklist in <u>Appendix A</u> provides a quick reference for identifying GHG emissions sources. Hyperlinks lead directly to the equations.

#### **IMPORTANT NOTES**

Other calculation methods than those presented in this section may be used. If so, they must be justified with supporting references and based on credible, reasonable, transparent, and conservative assumptions.

In addition, we reiterate that for a project subject to the RMRCECA and RCATS, the quantification methods in these regulations take precedence. In the case of other quantification exercises, these regulations may serve as acceptable references.

### 1.9 Emissions from Stationary Combustion Systems

GHG emissions from energy production in the form of electricity, heat, or steam using stationary combustion systems (e.g., furnace, boiler, generator, etc.) are calculated using the estimated quantity of the type of fuel consumed and the GHG emission factor corresponding to each type of fuel (i), in accordance with Equation 2.

#### **Equation 2: GHG Emissions from Stationary Combustion Sources**

Greenhouse gas emissions =  $\sum_{i=1}^{i=n} Amount of fuel i consumed \times Emission factor_i$ 

This equation can be used for all types of fuels, including fuels sourced from biomass.

Table 5. GHG Emission Factors of Fuels						
Fuel	CO <sub>2</sub>	CH4	N₂O	CO <sub>2</sub> eq	PCS	CO₂ eq (tonnes/GJ)
Natural gas	1 926 g/m³	0.037 g/m <sup>3</sup>	0.033 g/m <sup>3</sup>	1,930 g/m <sup>3</sup>	0.03986 GJ/m <sup>3</sup>	0.048
Renewable natural gas	1 805 g/m³ (*Biog.)	0.033 g/m <sup>3</sup>	0.033 g/m <sup>3</sup>	10 g/m <sup>3</sup>	0.0364 GJ/m <sup>3</sup>	0.0002
Ethane	986 g/l	0.024 g/l	0.108 g/l	1 015 g/l	0.01722 GJ/I	0.059
Propane	1 515 g/l	0.024 g/l	0.108 g/l	1 544 g/l	0.02534 GJ/I	0.061
Butane	1 747 g/l	0.024 g/l	0.108 g/l	1 776 g/l	0.02534 GJ/I	0.070
Light fuel oil	2 753 g/l	0.006 g/l	0.031 g/l	2 761 g/l	0.03835 GJ/I	0.072
Heavy fuel oil	3 156 g/l	0.120 g/l	0.064 g/l	3 176 g/l	0.04259 GJ/I	0.075
Diesel	2 681 g/l	0.078 g/l	0.022 g/l	2 689 g/l	0.03830 GJ/I	0.070
Gasoline	2 307 g/l	0.100 g/l	0,02	2 315 g/l	0.03345 GJ/I	0.069
Anthracite coal	2 382 g/kg	0.030 g/kg	0.02 g/kg	2 388 g/kg	0.02770 GJ/kg	0.086
Bituminous coal	2 222 g/kg	0.030 g/kg	0.02 g/kg	2 228 g/kg	0.02837 GJ/kg	0.079
Subbituminous coal	1 763 g/kg	0.030 g/kg	0.02 g/kg	1 769 g/kg	0.01848 GJ/kg	0.096
Lignite	1 462 g/kg	0.030 g/kg	0.02 g/kg	1 468 g/kg	0.01629 GJ/kg	0.090

Table 5 presents the most used GHG emission factors for fuels.

Table 5. GHG Emission Factors of Fuels						
Fuel	CO <sub>2</sub>	CH4	N <sub>2</sub> O	CO <sub>2</sub> eq	PCS	CO <sub>2</sub> eq (tonnes/GJ)
Petroleum coke (refineries and others)	3 776 g/l	0.120 g/l	0.027 g/l	3 837 g/l	0.04635 GJ/I	0.083
Petroleum coke (upgrading facilities)	3 494 g/l	0.120 g/l	0.023 g/l	3 503 g/l	0.04057 GJ/I	0.086
Coke (from coal)	3 173 g/kg	0.030 g/kg	0.020 g/kg	2 486 g/kg	0.02883 GJ/kg	0.086
Wood and wood waste (industrial)	1 715 g/kg (*Biog.)	0.100 g/kg	0.07 g/kg	21 g/kg	0.018 GJ/kg	0.0011
Wood and wood waste (residential)	1 539 g/kg (*Biog.)	12.90 g/kg	0.12 g/kg	393 g/kg	0.018 GJ/kg	0.022

Source: Emission factors adapted from Part 2 of the National Inventory Report (NIR) 1990-2022, Appendix 6.

# 1.10 Emissions from Mobile Combustion Systems

The sources covered, including those used by subcontractors, are:

- a) Any mobile equipment typically used at a facility or installation site for transporting or carrying substances, materials, or products
- b) Any mobile equipment (e.g., tractor, crane, grader, backhoe loader, or bulldozer) used to carry out construction, operation (e.g., ore transfer or hauling activities), or closure activities for the project
- c) Emissions from the transportation of incoming materials required for construction and operation
- d) Emissions from the transportation of outgoing excavation and backfill materials generated by construction and operation
- e) Emissions from mobile equipment used directly or indirectly by certain activities such as transportation of workers, raw materials, or finished products.

Emissions from mobile combustion systems are estimated with Equation 3 for each fuel type (i). Note that Equation 3 is similar to Equation 2, but the emission factors differ.

#### Equation 3: GHG emissions from the use of mobile equipment

Greenhouse gas emissions = 
$$\sum_{i=1}^{i=n} Amount of fuel i consumed \times Emission factor_i$$

For GHG emission factors associated with fuels, refer to the Table 6 and Table .

Table 6. Emission Factors for Energy Mobile Combustion Sources				
Mobile Equipment	g CO <sub>2</sub> /litre	g CH <sub>4</sub> /litre	g N <sub>2</sub> O/litre	g CO <sub>2</sub> eq/litre
Light-duty Gasoline Vehicles (LDGVs)		Ŭ		
Tier 3	2 307	0.11	0,007	2312
Tier 2	2 307	0.14	0,022	2317
Tier 1	2 307	0.23	0,47	2438
Tier 0	2 307	0.32	0,66	2491
Oxidation Catalyst	2 307	0.52	0,20	2375
Non-catalytic Controlled	2 307	0.46	0.028	2327
Light-duty Gasoline Trucks (LDGTs)			,	
Tier 3	2 307	0.11	0,007	2312
Tier 2	2 307	0.14	0,022	2317
Tier 1	2 307	0.24	0,58	2467
Tier 0	2 307	0.21	0,66	2488
Oxidation Catalyst	2 307	0.43	0,20	2372
Non-catalytic Controlled	2 307	0.56	0,028	2330
Heavy-duty Gasoline Vehicles (HDGVs)				
Three-way Catalyst	2 307	0.068	0,20	2362
Non-catalytic Controlled	2 307	0.29	0.047	2 328
Uncontrolled	2 307	0.49	0.084	2 343
Motorcycles				
Non-catalytic Controlled	2 307	0.77	0.041	2 339
Uncontrolled	2 307	2.3	0.048	2 384
Light-duty Diesel Vehicles (LDDVs)				
Advanced Control	2 681	0.051	0.22	2 741
Moderate Control	2 681	0.068	0.21	2 739
Uncontrolled	2 681	0.10	0.16	2 726
Light-duty Diesel Trucks (LDDTs)				
Advanced Control	2 681	0.068	0.22	2 741
Moderate Control	2 681	0.068	0.21	2 739
Uncontrolled	2 681	0.085	0.16	2 726
Heavy-duty Diesel Vehicles (HDDVs)				
Advanced Control	2 681	0.11	0.151	2 724
Moderate Control	2 681	0.14	0.082	2 707
Uncontrolled	2 681	0.15	0.075	2 705
Natural Gas Vehicles	1.9	0.0088	0.00006	2
Propane Vehicles	1 515	0.64	0.028	1 540
Off-road Vehicles				
Off-road Gasoline 2-stroke	2 307	10.56	0.013	2 606
Off-road Gasoline 4-stroke	2 307	5.08	0.064	2 466
Off-road Diesel < 19kW	2 681	0.073	0.022	2 689
Off-road Diesel ≥19kW, Tier 1-3	2 681	0.073	0.022	2 689
Off-road Diesel ≥19kW, Tier 4	2 681	0.073	0.227	2 743
Off-road Natural Gas	1.9	0.0088	0.00006	2
Railways				
Diesel Train	2 681	0.15	1.029	2 958
Aviation	1			
Aviation Gasoline	2 325	2.19	0.23	2 447
Aviation Turbo Fuel	2 560	0.018	0.071	2 579

Table 6. Emission Factors for Energy Mobile Combustion Sources				
Mobile Equipment	g CO <sub>2</sub> /litre	g CH₄/litre	g N <sub>2</sub> O/litre	g CO <sub>2</sub> eq/litre
Marine Transport				
Gasoline	2 307	0.219	0.063	2 339
Diesel	2 681	0.252	0.072	2 707
Light Fuel Oil	2 753	0.255	0.073	2 779
Heavy Fuel Oil	3 156	0.2856	0.0816	3 186
Kerosene	2 560	0.2471	0.0706	2 586

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A6.1-15 – Emission Factors for Energy Mobile Combustion Sources.

Table 7. Emission Factors for Biofuels					
Liquid biofuels	Biogenic emissions Non-biogenic emissions				
	Emission factor	Emission factor	Emission Factor		
	(g CO₂/litre)	(g CH₄/litre)	(g N₂O/litre)		
Ethanol (100%)	1 508	0.14	0.022		
Biodiesel (100%)	2 472	0.11	0.151		
Gaseous biofuels	Biogenic emissions	Non-biogenio	emissions		
	Emission factor	Emission factor	Emission factor		
	(g CO <sub>2</sub> /m³)	(g CH₄/m³)	(g N <sub>2</sub> O/m <sup>3</sup> )		
Biogas	1 887	0.037	0.033		

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A6.1-15 – Emission Factors for Energy Mobile Combustion Sources. \*\*At standard temperature and pressure conditions.

For GHG emissions from the use of off-road mobile equipment, fuel consumption can also be estimated from the BSFC<sup>5</sup> factor, which represents the diesel consumption of the equipment per horsepower for each hour of operation. This factor is expressed in pounds of diesel per horsepower per hour and can be determined with the use of Tables A4, C1, and C2 in the document "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition" in MOVES201X, published by the United States Environmental Protection Agency (US EPA)<sup>6</sup>.

# 1.11 Indirect GHG Emissions from Electrical Energy Consumption

Annual indirect GHG emissions from electricity consumption (grid-based) can be determined from the annual electricity consumption and the GHG emission factor associated with electricity generation in Quebec. Table A13-6 in Environment and Climate Change Canada's National Inventory Report<sup>7</sup> shows the grams of CO<sub>2</sub> equivalent emitted per kilowatt-hour of electricity generated in Quebec. Since the inventory reports are annual, the factors used must be the most recent.

If the electricity is generated by a thermal power plant, the GHG emissions can also be calculated from the expected annual electricity consumption and the plant's GHG emissions intensity (in grams of CO<sub>2</sub> equivalent per kilowatt-hour).

<sup>&</sup>lt;sup>5</sup> Brake-Specific Fuel Consumption. <u>https://nepis.epa.gov/Exe/ZyPDF.cgi/P10005BI.PDF?Dockey=P10005BI.PDF</u>

<sup>6</sup> Ibid

<sup>&</sup>lt;sup>7</sup> National Inventory Report 1990-2022. Part 3, Table A13-6. Electricity Generation and Greenhouse Gas Emissions Data for Quebec.

# 1.12 GHG Emissions from Industrial Processes

The <u>RMRCECA</u> is the main reference for the quantification of GHG emissions from the industrial sector. As a reminder, see the cautionary note in the introduction about the precedence of the standards and methods prescribed by this regulation.

Table 8 presents the list of RMRCECA protocols applicable to the quantification of GHG emissions for different emitting activities in progress. For information purposes, the table also provides a non-exhaustive list of the main sources of emissions associated with these activities.

If none of the protocols in the table are applicable to the type of process or equipment used, other methods for quantifying GHG emissions should be used. When applicable, the methodology and detailed calculations should be specified and supporting references should be provided. Quantification methods must be reliable, recognized, and verifiable.

Table 8. Protocols for Quantifying GHG Emissions from Some Industrial Sectors Covered by the RMRCECA				
Sector	RMRCECA Protocols	Description and Major Sources of GHGs <sup>8 9 10 11 12</sup>		
Aluminium production	QC.3	<ul> <li>In the primary aluminium production process (Hall-Heroult), GHG emissions will vary depending on the different technologies (related to anodes and alumina feed): prebaked center-pit anodes, prebaked peripheral-pit anodes, horizontal stud Søderberg and vertical stud Søderberg. In Quebec, the last two technologies no longer exist.</li> <li>The most significant GHG emissions are: <ul> <li>i) CO<sub>2</sub> emissions from the consumption of carbon anodes in the reaction converting aluminium oxide to aluminium metal</li> <li>(ii) PFC emissions from CF<sub>4</sub> and C<sub>2</sub> F<sub>6</sub> during anode effects.</li> </ul> </li> </ul>		
Cement production	QC.4	Limestone (CaCO <sub>3</sub> ), dolomite (CaMg(CO <sub>3</sub> ) <sub>2</sub> ) and other carbonates (e.g., MgCO <sub>3</sub> and FeCO <sub>3</sub> ) are basic raw materials with commercial applications, notably in the production of cement, lime, and glass. Carbonates are also consumed in metallurgy (e.g., steel and metallurgy), agriculture, and construction. The calcination of carbonates at high temperature releases CO <sub>2</sub> .		
Coal storage	QC.5	Coal gas consists primarily of CH <sub>4</sub> , which is trapped in the core of the solid coal matrix. Therefore, during storage, CH <sub>4</sub> passively escapes, and its magnitude depends on the amount stored and the source of the coal.		
Hydrogen production	QC.6	Hydrogen is mainly produced from energy sources by reforming fossil fuels (natural gas, liquid hydrocarbons, and coal). Therefore, its production is a significant source of GHG emissions. However, the		

<sup>8</sup> RMRCECA and 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

<sup>&</sup>lt;sup>9</sup> IPCC, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3\_Volume3/V3\_3\_Ch3\_Chemical\_Industry.pdf.

<sup>&</sup>lt;sup>10</sup> IPCC, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3\_Volume3/V3\_4\_Ch4\_Metal\_Industry.pdf.

<sup>&</sup>lt;sup>11</sup> IPCC 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3\_Volume3/V3\_2\_Ch2\_Mineral\_Industry.pdf.

<sup>&</sup>lt;sup>12</sup> IPCC, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3\_Volume3/V3\_6\_Ch6\_Electronics\_Industry.pdf.

Table 8. Protocols for Quantifying GHG Emissions from Some Industrial Sectors			
		Covered by the RMRCECA	
Sector	RMRCECA	Description and Major Sources of GHGs <sup>8</sup> 9 <sup>10</sup> <sup>11</sup> <sup>12</sup>	
	Protocols	production of hydrograp by water electrolysic is evoluted from the	
		calculations.	
Iron and steel	QC.7	The production of iron and steel from iron ore generates emissions of $CO_2$ , $CH_4$ , and $N_2$ O.	
Lime production	QC.8	See QC.4.	
Oil refineries	QC.9	The sources covered include all processes used for the production of gasoline, aromatic hydrocarbons, kerosene, light and heavy fuel oils, diesel, lubricants, bitumen, or other products obtained by distillation of petroleum or by redistillation, cracking, rearrangement, or reforming of petroleum derivatives.	
Pulp and paper manufacturing	QC.10	<ul> <li>The sources covered are GHG emissions related to:</li> <li>The use of stationary combustion equipment</li> <li>Biomass combustion</li> <li>Electricity generation</li> <li>Anaerobic wastewater treatment.</li> <li>Note that the QC.10 protocol is used to collect specific information and does not include calculation methods. This protocol refers to other protocols for the calculation of emissions.</li> </ul>	
Soda ash production	QC.11	Soda ash (Na <sub>2</sub> CO <sub>3</sub> ) is used as a raw material in a wide range of industries, including glass, soap, detergent, and pulp and paper manufacturing. The GHGs emitted are CO <sub>2</sub> , and emissivity varies depending on the type of process.	
Petrochemical manufacturing	QC.12	The petrochemical industry uses primary fossil fuels (natural gas, oil, coal) and other petroleum products for non-fuel, i.e. non-energy purposes.	
Adipic acid production	QC.13	Adipic acid is used in the manufacture of several products, including synthetic fibers (nylon), coatings, plastics, urethane foams, and synthetic lubricants. Adipic acid is a significant source of $N_2O$ .	
Lead production	QC.14	The main processes used in the primary production of lead (agglomeration/smelting and direct smelting) involve combustion in furnaces. Both processes generate non-energy CO <sub>2</sub> (e.g., use of reducing agents such as metallurgical coke and natural gas). Secondary lead production (recycling) also generates CO <sub>2</sub> .	
Zinc production	QC.15	Various primary zinc production processes (e.g. electrothermal, pyrometallurgical and hydrometallurgical) involve combustion. These processes emit non-energy CO <sub>2</sub> (e.g., use of reducing agents such as metallurgical coke and natural gas).	
Nickel and copper production	QC.18	The processes involved are those related to the removal of impurities from the nickel or copper concentrate by adding carbonate reagents, the extraction of metals from oxidized ores with reducing agents for slag cleaning, the consumption of electrodes in electric arc furnaces, and the	

Table 8. Protocols for Quantifying GHG Emissions from Some Industrial Sectors Covered by the RMRCECA			
Sector	RMRCECA	Description and Major Sources of GHGs <sup>8 9 10 11 12</sup>	
	Protocols		
		removal of carbon-containing raw materials, such as recycled raw materials.	
Production of ferroalloys	QC.19	Ferroalloys are concentrated alloys of iron and one or more other metals such as manganese, silicon, chromium, molybdenum, vanadium, or tungsten. The production of ferroalloys involves a metallurgical reduction process that results in significant CO <sub>2</sub> emissions.	
Magnesium production	QC.20	Primary magnesium can be produced by electrolysis or thermal reduction. Raw materials used include dolomite, magnesite, and serpentine. The processing of raw materials releases $CO_2$ . The production and casting of any magnesium metal requires a protective system to prevent combustion, and some of these systems use $SF_6$ , a GHG with a global warming potential approximately 23,000 times greater than $CO_2$ .	
Nitric acid production	QC.21	Nitric acid (HNO <sub>3</sub> ) is used as a raw material primarily in the manufacture of nitrogen-based fertilizers, in the production of adipic acid and explosives (e.g., dynamite), and in metal etching and ferrous metal processing. The production of nitric acid (HNO <sub>3</sub> ) can be a significant source of N <sub>2</sub> O emissions.	
Phosphoric acid production	QC.22	Phosphoric acid is generally produced by the reaction between phosphate rock and sulfuric acid. In addition, a second reaction occurs between the carbonates present in the ore (mainly calcium carbonate) and sulfuric acid releasing CO <sub>2</sub> . The amount of carbonates present in the ore depends on the region from which the ore is taken.	
Ammonia production	QC.23	The production of ammonia (NH <sub>3</sub> ) requires a source of nitrogen (N) and hydrogen (H). Most of the ammonia production uses natural gas (mainly methane [CH <sub>4</sub> ]).	
Electricity transmission and distribution and use of equipment to produce electricity	QC.24	Sulfur hexafluoride (SF <sub>6</sub> ) is used for electrical insulation and current interruption in equipment used for the transmission and distribution of electricity. SF <sub>6</sub> and CF <sub>4</sub> can also be used in electrical substations, circuit breakers, and high-voltage lines. GHG emissions occur at every phase of the equipment life cycle, including manufacturing, installation, use, maintenance, and disposal.	
Carbonates use	QC.25	See QC.4.	
Glass production	QC.26	The main raw materials used in the glass industry that emit CO <sub>2</sub> during the melting process are limestone (CaCO <sub>3</sub> ) and dolomite (CaMg(CO <sub>3</sub> ) <sub>2</sub> ), both carbonates, as well as soda ash (Na <sub>2</sub> CO <sub>3</sub> ). See also QC.4.	
Electronics manufacturing	QC.28	The main GHGs emitted by this industry are NF <sub>3</sub> (17,200 times more potent than $CO_2$ in terms of global warming potential), SF <sub>6</sub> (nearly 23,000 times more potent than $CO_2$ ), and PFCs (7,000 to nearly 18,000 times more potent than $CO_2$ ), which are used at important stages of electronics manufacturing (plasma etching and chemical deposit cleaning).	
Natural gas	QC.29	The covered sources are:	
transportation and		<ul> <li>Compression of natural gas for land transportation</li> </ul>	

Table 8. Protocols for Quantifying GHG Emissions from Some Industrial Sectors Covered by the RMRCECA			
Sector	RMRCECA Protocols	Description and Major Sources of GHGs <sup>8 9 10 11 12</sup>	
distribution (processes and equipment)		<ul> <li>Underground storage of natural gas</li> <li>Liquefied natural gas (LNG) storage</li> <li>Import and export of LNG</li> <li>Natural gas transmission pipelines</li> <li>Natural gas distribution, which includes any equipment downstream of the shut-off valves on transmission pipelines where pressure reduction first occurs for the delivery of natural gas to consumers.</li> </ul>	
Titanium dioxide production <sup>19</sup>	QC.31	Titanium dioxide (TiO <sub>2</sub> ) is mainly used in the manufacture of paint, then for the manufacture of paper, plastics, rubber, etc. The CO <sub>2</sub> emissions of TiO <sub>2</sub> are associated with the chemical reaction process.	
Titanium dioxide slag from ilmenite reduction and molten cast iron treatment <sup>19</sup>	QC.32	Titanium dioxide slag is used as material for the production of titanium dioxide (TiO <sub>2</sub> ) (see QC.31). The CO <sub>2</sub> emissions are mainly attributable to the reduction of ilmenite from coal.	
Oil and natural gas exploration and production and natural gas processing	QC.33	These sources of GHG emissions are related to the processes and equipment used in oil and gas exploration and development in aquatic and terrestrial environments.	
Iron and steel powder production	QC.34	<ul> <li>These sources of GHG emissions are related to the following processes:</li> <li>Atomization of molten cast iron</li> <li>Decarburization of iron powder</li> <li>Steel grading</li> <li>Annealing of steel powder.</li> </ul>	

Sources: RMRCECA and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006).

# 1.13 GHG Emissions from Mining and Mineral Processing

The mining sector has specific characteristics that must be taken into account in the quantification of GHG emissions. Among these particularities is the location of a mine in an area not served by the main electrical grid. If the electricity is produced by a fleet of generators or by a thermal power plant, GHG emissions can be calculated from the expected annual electricity consumption and the GHG emission intensity (in grams of CO<sub>2</sub> equivalent per kilowatt-hour) of this electrical production. If the electricity is sourced from the main electricity grid, emissions can be calculated from the equation presented in the section on <u>indirect emissions</u> from electrical energy consumption.

GHG emissions from the use of stationary combustion equipment can be calculated from the equation presented in the <u>section on stationary combustion systems</u>. GHG emissions from the transportation of ore to

the processing plant can be calculated using the equation presented in the <u>Section 1.10</u> on mobile combustion systems. The calculation of emissions from the use of explosives is presented in <u>Section 1.16</u>.

In addition, some ore transformation processes vary by ore type and have specific characteristics that are presented in the following sections. Sections 3.5.1 and 3.5.2 present two transformation processes (iron pellet production and carbonate use) whose sources and quantification methodologies are based on the RMRCECA. The third section discusses mineral transformation processes that are not covered by a specific RMRCECA protocol.

#### 1.13.1 Calculation of GHG emissions from iron pellet production

The RMRCECA protocol QC.7 ("Iron and Steel Production") can be used to calculate process GHG emissions from the production of iron pellets.

#### 1.13.2 Calculation of GHG emissions from the use of carbonates in a process

GHG emissions from this process occur primarily in the lime kiln, where carbonates (limestone-based raw materials [CaCO<sub>3</sub>, MgCO<sub>3</sub>]) are calcined at high temperatures to produce quicklime (CaO) or dolomitic lime (CaO-MgO). This calcination reaction generates CO<sub>2</sub> emissions.<sup>13</sup>

The RMRCECA QC.25 protocol can be used to estimate the GHG emissions from this process.

#### 1.13.3 Other GHG emissions from mineral processing

To calculate GHG emissions from mineral processing operations other than those mentioned, the RMRCECA quantification methodologies can be used, including QC.14, QC.15, QC.18, QC.19 and QC.32.

#### 1.13.4 GHG Emission Factors from Commonly Used Mineral Products Production

Table 9 presents emission factors used to estimate GHG emissions from the production and use of mineral products.

Table 9. CO <sub>2</sub> Emission Factors for Mineral Products			
Category	Mineral Product	Emission Factor (g CO <sub>2</sub> eq/kg of product)	
Cement Production	Clinker	520 - 533	
	Total Organic Carbon (TOC)	10.6 - 12.2	
Lime Production	High-Calcium Lime	751 - 756	
	Dolomitic Lime	869 - 889	
Other Limestone and Dolomite Use	Limestone	418 - 425	
	Dolomite	458 - 468	
Other Uses of Soda Ash	Soda Ash	415	
Non-Metallurgical Magnesia Production	Magnesite	522	

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A6.2-1 – Range of CO<sub>2</sub> Emission Factors for Mineral Products.

<sup>&</sup>lt;sup>13</sup> ECCC, 2004. Guide pour l'estimation des émissions de GES (Guidance manual for estimating greenhouse gas emissions). http://publications.gc.ca/collections/Collection/En49-2-9-5F.pdf.

#### 1.13.5 GHG Emission Factors from the Iron and Steel Industry

CO<sub>2</sub> emission factors for the iron and steel industry as well as the carbon contents of certain steels and irons are presented in Tables 10 and 11.

Table 10. CO <sub>2</sub> Emission Factors for the Iron and Steel Industry			
Parameter	Emission Factor	Unit	
Iron ore reduction with coke	3.1 – 3.3	t CO <sub>2</sub> / t coke used	
Electrode consumption in electric arc furnaces	4.5 – 7.7	kg CO <sub>2</sub> / t steel	
Emissions from basic oxide furnaces	0.14 – 0.23	kg CO <sub>2</sub> / t steel	
Limestone use	418 - 425	kg CO <sub>2</sub> / t CaCO <sub>3</sub>	
Dolomite use	458 - 468	kg CO <sub>2</sub> / t MgCO <sub>3</sub>	

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A6.2-6 - Range of CO2 Emission Factors for the Iron and Steel Industry

Table 11. Carbon Contents for the Iron and Steel Industry			
Parameter	Carbon Contents (%)		
Pig iron (production of pig iron) from BFs	4.4 – 4.7		
Pig iron (includes hot metal, cold iron, DRI and pig iron) for steel making			
Crude steel produced in BOF			
Crude steel produced in EAF	0.14 – 0.26		
Scrap steel	0.1 – 0.9		

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A6.2-7 - Range of Carbon Contents for the Iron and Steel Industry

#### 1.13.6 GHG Emission Factors for Aluminium Production

Emission factors for tier 1 aluminium production are presented in Table 12.

Table 12. Emission Factors for Aluminium Production			
Cell Technology Type	Emission Factors (kg / t product)		
	CO <sub>2</sub>	Carbon Tetrafluoride	Carbon Hexafluoride
		(CF <sub>4</sub> ) <sup>(a)</sup>	(C <sub>2</sub> F <sub>6</sub> ) <sup>(b)</sup>
Side-worked pre-baked	1 600	1.6	0.4
Centre-worked pre-baked	1 600	0.4	0.04
Horizontal stud Söderberg	1700	0.4	0.03
Vertical stud Söderberg	1700	0.8	0.04

Source: International Aluminium Institute  $(2006)^{14}$ a) PRP du CF<sub>4</sub> = 7 390<sup>15</sup>

b) PRP du C2F6 = 12 20016

<sup>&</sup>lt;sup>14</sup> International Aluminium Institute. 2006. The aluminium sector greenhouse gas protocol (Addendum to the WRI/WBCSD Greenhouse Gas Protocol).

<sup>&</sup>lt;sup>15</sup> https://www.environnement.gouv.qc.ca/changements/ges/registre/tableaux.htm

<sup>&</sup>lt;sup>16</sup> https://www.environnement.gouv.gc.ca/changements/ges/registre/tableaux.htm

# 1.14 GHG Emissions from Hydrogen Production and Use

#### 1.14.1 Hydrogen Production and Use

As mentioned in Table 8, an industrial hydrogen producer established in Quebec is required to make its annual GHG emissions report in accordance with the RMRCECA QC.6 protocol. This calculation of GHG emissions can be done either with a continuous emissions measurement and recording system or a complete mass balance of the production plant.

To quantify GHG emissions from hydrogen acquired and used as fuel or feedstock, it is suggested to use Equation 4.

#### Equation 4: GHG Emissions from Hydrogen Use

$$E_{GHG_{H2}} = Q_{H2} \times EF_{H2}$$

Where:

 $E_{GHG_H2}$  = GHG emissions associated with the use of hydrogen as a fuel or feedstock, expressed in tonnes of CO<sub>2</sub> equivalent

Q<sub>H2</sub> = Quantity of hydrogen consumed, in tonnes

 $EF_{H2}$  = GHG emission factor associated with hydrogen production, in tonnes of CO<sub>2</sub> equivalent per tonne of hydrogen

GITO ETHISSION IACIOIS ION UNEVENTILI TADIE	ypes of hydrogen production proc	esses are shown in Table 13
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Table 13. GHG Emission Factors by Type of Process of Hydrogen Production				
Type of Process	EF (t CO <sub>2</sub> eq./ t H <sub>2</sub> )			
Steam Methane Reforming (SMR)		10		
Autothermal Reforming (ATR)		8.98		
SMR with CO <sub>2</sub> Capture and Sequestration (SMR-CCS)		5		
ATR with CO <sub>2</sub> Capture and Sequestration (ATR-CCS)		0.45		
Electrolysis	Quebec	0.075		
	Alberta	33.5		
	British Columbia	0.985		
	Prince Edward Island	0.1		
	Manitoba	0.065		
	New Brunswick	13.5		
	Nova Scotia	38		
	Ontario	1.5		
	Saskatchewan	35.5		
	Newfoundland and Labrador	1.4		
Table 13. GHG Emission Factors by Type of Process of Hydrogen Production				
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Type of Process		EF (t CO <sub>2</sub> eq./ t H <sub>2</sub> )		
	Northwest Territories	10		
	Yukon	5.65		

Source: Draft technical guide related to the strategic assessment of climate change - Government of Canada, August 2021

#### 1.14.2 Evolution of Knowledge on Hydrogen

In 2020, 95% of the world's hydrogen production was composed of grey hydrogen, which is produced by reforming fossil fuels (mainly methane and coal). Of the hydrogen produced, 25% is used in refineries, 65% in ammonia production, and 10% in various industrial sectors, including the steel industry<sup>17</sup> <sup>18</sup>.

In a context of climate transition, some experts see great potential for hydrogen use in heavy transport. Green hydrogen, produced from water electrolysis, could also replace grey hydrogen for industrial uses. However, knowledge on the impacts of this sector is evolving rapidly, and it is important to present the main interventions of scientists on this subject.

The IPCC<sup>19</sup> considers hydrogen as part of the portfolio of energy options to mitigate GHG emissions. However, the organization mentions a potential indirect impact of hydrogen emissions on the increase of the greenhouse effect while specifying that the scientific advances are not sufficiently documented at this time.

According to other experts, hydrogen is an indirect greenhouse gas. Through a series of chemical reactions, it would slow down the destruction of certain greenhouse gases in the atmosphere, such as methane, which would accelerate global warming. Fugitive hydrogen emissions would then be a problem and must be well controlled. Otherwise, the gains anticipated from the use of hydrogen could be cancelled out. Although these numbers are not yet endorsed by the scientific community, some authors attribute to hydrogen a global warming potential over 100 years between 11 and 15, compared to 1 for CO<sub>2</sub>. Moreover, many question the energy balance of hydrogen production over its life cycle, which they consider to be very energy consuming, even in the case of green hydrogen production  $20 \ 21 \ 22 \ 23 \ 24 \ 25$ .

Under such circumstances and as a precautionary principle, it is necessary to take into account the evolution of knowledge on the impacts of hydrogen on climate change when carrying out projects related to this sector

<sup>&</sup>lt;sup>17</sup> Transition énergétique Québec, 2020. Étude sur le potentiel de la filière de l'hydrogène au Québec dans la transition énergétique (Webinaire) (Study on the potential of the hydrogen sector in the energy transition [Webinar]).

https://transitionenergetique.gouv.qc.ca/fileadmin/medias/pdf/expertises/PPT\_webinaire\_H2\_20200714.pdf

<sup>&</sup>lt;sup>18</sup> Polytechnique Montréal, 2020. Étude sur le potentiel technico-économique du développement de la filière de l'hydrogène au Québec et son potentiel pour la transition énergétique, volet A : portrait régional, canadien et international actuel de l'économie de l'hydrogène (Study on the techno-economic potential of the development of Quebec's hydrogen sector and its potential for the energy transition, component A: Regional, Canadian and international portrait of the hydrogen economy). https://transitionenergetique.gouv.gc.ca/fileadmin/medias/pdf/expertises/Etude\_hydrogene\_Volet\_A.pdf.

<sup>&</sup>lt;sup>19</sup> IPCC, 2021. Climate Change 2021: The Physical Science Basis. <u>Climate Change 2021: The Physical Science Basis | Climate Change 2021: The Physical Science Basis (ipcc.ch)</u>

<sup>&</sup>lt;sup>20</sup> Warwick N. et al, April 2022. Atmospheric implications of increased hydrogen use. <u>Atmospheric implications of increased hydrogen use</u> (<u>publishing.service.gov.uk</u>).

 <sup>&</sup>lt;sup>21</sup> US Environmental Defense Fund, 2022. <u>Clean or dirty: Is hydrogen the climate-friendly energy solution we need?</u> <u>Environmental Defense Fund (edf.org)</u>
<sup>22</sup> US Environmental Defense Fund, 2022. <u>https://www.edf.org/article/we-need-talk-about-hydrogen</u>

<sup>&</sup>lt;sup>23</sup> European Geosciences Union, Atmospheric Chemistry and Physics, 2022. <u>ACP - Climate consequences of hydrogen emissions (copernicus.org)</u>

<sup>&</sup>lt;sup>24</sup> L'hydrogène est-il la solution à nos problèmes énergétiques ? (Is hydrogen the solution to our energy issues?) (futura-sciences.com)

<sup>&</sup>lt;sup>25</sup> École des Hautes Études commerciales (HEC), 2022. État de l'énergie au Québec (State of energy in Quebec). EEQ2022 web.pdf (hec.ca)

and to readjust if necessary. In some cases, an upstream indirect emission's assessment or life cycle analysis may be required to determine the project's carbon footprint and its actual effect on climate change.

## 1.15 GHG Emissions from the Chemical Industry

Table 14.	Emission Factors for C	Chemical Products Production
Chemical Product	Emission Factor	Note
Ammonia	671 m <sup>3</sup> natural gas/tonne of	Emission factors for marketable natural gas are
	NH <sub>3</sub>	presented in Table 5.
Nitric Acid	0.554 kg N <sub>2</sub> O / t	Sector-wide weighted average in 2022
Adipic Acid	300 kg N <sub>2</sub> O / t	Oxidation reaction of cyclohexanone and cyclohexanol
		mixture without N <sub>2</sub> O abatement
Silicon Carbide	11.6 kg CH₄ / t	IPCC default
Calcium Carbide	4.8 kg CH <sub>4</sub> / t	Derived from CH <sub>4</sub> emission factor for silicon carbide
		and the ratio of IPCC default Calcium Carbide CO2
		emission factor to IPCC default Silicon Carbide CO <sub>2</sub>
		emission factor
Carbon Black	1.29 kg CH <sub>4</sub> / t	Sector-wide weighted average
	0.032 kg N <sub>2</sub> O / t	
Ethylene	0.411 t CO <sub>2</sub> / t	Sector-wide weighted average
	0.039 kg CH <sub>4</sub> / t	
	0.0055 kg N <sub>2</sub> O / t	
Ethylene Dichloride	0.0142 kg CH <sub>4</sub> / t	Sector-wide weighted average
Ethylene Oxide	0.5202 t CO <sub>2</sub> / t	Sector-wide weighted average
	1.79 kg CH <sub>4</sub> / t	
Styrene	4 kg CH <sub>4</sub> / t	Sector-wide weighted average
Methanol	0.790 t CO <sub>2</sub> / t	Sector-wide weighted average
	0.031 kg CH <sub>4</sub> / t	
	0.010 kg N <sub>2</sub> O / t	
HCFC-22	0.04 t HFC-23 emitted / t	IPCC default
	HCFC-22 produced	
Other Uses of Urea	0.733 t CO <sub>2</sub> / t	IPCC default

Table 14 presents the emission factors for the production of certain chemical products used frequently.

Source: Adapted from the National Inventory Report (NIR) 1990-2022. Part II. Table A6.2-2, A2.2-3 et A6.2-4

### 1.16 GHG Emissions from Explosives Use

Explosives emit GHGs during detonation. Explosives can be used in a variety of projects, including mining, road and transportation infrastructure projects (ports, airports, etc.). The GHG emissions from the use of explosives can be calculated from Equation 5<sup>26</sup>.

#### Equation 5: GHG Emissions from the Use of Explosives

$$E_{CO2\_Exp} = \sum_{n=1}^{n=12} 3.664 \times (FFexp_n \times CC_n) \times 0.001$$

Where:

 $ECO_{2\_Exp}$  = Annual CO<sub>2</sub> emissions from the consumption of fossil fuels used in explosives, expressed in tonnes per year

 $FFexp_n$  = Fossil fuel mass contained in explosives used in month *n*, expressed in kilograms of fuel  $CC_n$  = Average carbon content of the fossil fuel used in the explosive in month *n*, expressed in kilograms of carbon per kilogram of fossil fuel

3.664 = Molecular weight ratio of CO<sub>2</sub> to carbon

0.001 = Conversion factor from kilograms to tonnes

Some commonly used explosives have specific CO<sub>2</sub> emission factors, which are shown in Table 15.

Table 15. CO <sub>2</sub> Emission Factors for Selected Explosives				
Type of Explosive	EF (tonnes CO <sub>2</sub> / tonne of explosive)			
ANFO	0.17			
Heavy ANFO	0.18			
Emulsion	0.17			

Source: National Greenhouse Accounts (NGA) Factors. Updating and replacing the AGO Factors and Methods Workbook. Australian Government. Department of Climate Change. January 2008. <u>National Greenhouse Accounts (NGA) Factors</u>.

Therefore, if the CO<sub>2</sub> emission factor of the explosive is known, the GHG emissions associated with their use can be calculated very easily from Equation 6.

#### Equation 6: GHG Emissions from Explosives Use

$$E_{CO2\_Exp} = M_{Exp} \times EF_{Exp}$$

Where:

 $ECO_{2_{Exp}}$  = Annual CO<sub>2</sub> emissions from the consumption of fossil fuels used in explosives, expressed in tonnes

*M*<sub>Exp</sub> = Mass of explosive used, in tonnes

 $EF_{Exp}$  = CO<sub>2</sub> emission factor of the explosive, in tonnes of CO<sub>2</sub> per tonne of explosive

<sup>&</sup>lt;sup>26</sup> A Guidance Document for Reporting Greenhouse Gas Emissions for Large Industry in Newfoundland and Labrador. Government of Newfoundland and Labrador. Office of Climate Change. March 2017. http://www.exec.gov.nl.ca/exec/occ/greenhouse-gas-data/GHG\_Reporting\_Guidance\_Document.pdf.

## 1.17 GHG Emissions from Fugitive Emissions of Sulfur Hexafluoride and Perfluorocarbons

 $SF_6$  emissions from magnesium production are discussed in <u>section 1.12</u> on industrial processes. This activity is covered by a quantification protocol in the RMRCECA (QC.20).

Sulphur hexafluoride (SF<sub>6</sub>) and perfluorocarbon (PFC) emissions discussed here are more likely to be associated with electricity transmission and distribution. The impact of these emissions is primarily due to their fugitive nature (meaning that they are difficult to control) and their high global warming potentials. The warming potential of SF<sub>6</sub> is nearly 23,000 times that of CO<sub>2</sub>, and the warming potential of PFCs can be nearly 18,000 times that of CO<sub>2</sub>. The other issue is that these gases have replaced deleterious substances (such as polychlorinated biphenyls, i.e., PCBs) and there is no less emissive alternative to date. From the point of view of energy security, knowledge of the impacts of these substances, application of good practices, and research and development are the best options.

During the operation of electricity transmission and distribution equipment, fugitive emissions of  $SF_6$  or PFCs may occur in connection with:

- Gas handling and transfer operations
- Equipment operation
- Mechanical failure of equipment.

To calculate fugitive SF<sub>6</sub> or PFC emissions from electricity distribution, the Canadian Electricity Association's<sup>27</sup> emission factor methodology can be used, according to Equations 7 and 8.

## Equation 7: Estimated GHG Emissions from SF<sub>6</sub>-containing Equipment used in Electricity Transmission and Distribution

$$E_{SF6} = (0.01 \times Lot_{SF6} + 0.7 \times LoiSF6_{DE}) \times GWP_{SF6} \times 0.001$$

Where:

 $E_{SF6}$  = GHG emissions attributable to the use of SF<sub>6</sub>, expressed in tonnes of CO<sub>2</sub> equivalent per year LotSF<sub>6</sub> = Total SF<sub>6</sub> load in existing equipment during year t, expressed in kilograms of SF<sub>6</sub> per year LoiSF6<sub>DE</sub> = Initial SF<sub>6</sub> load in discarded equipment, expressed in kilograms of SF<sub>6</sub> per year GWP<sub>SF6</sub> = Global warming potential of SF<sub>6</sub>

0.001 = Conversion factor from kilograms to tonnes

<sup>&</sup>lt;sup>27</sup> Environment Canada. Canadian Electricity Association. Annex A: SF6 Emission Estimation and Reporting Protocol for Electric Utilities (Final Version). Page 32. https://publications.gc.ca/collections/collection\_2013/ec/En4-229-2008-eng.pdf

## Equation 8: Estimated GHG Emissions from PFC-containing Equipment used in Electricity Transmission and Distribution

$$E_{PFC} = (0.01 \times Lot_{PFC} + 0.7 \times LoiPFC_{DE}) \times GWP_{PFC} \times 0.001$$

Where:

 $E_{PFC}$  = GHG emissions attributable to the use of PFCs, expressed in tonnes of CO<sub>2</sub> equivalent per year Lot<sub>PFC</sub> = Total PFC load in existing equipment during year t, expressed in kilograms of PFCs per year LoiPFC<sub>DE</sub> = Initial load of PFCs in discarded equipment, expressed in kilograms of PFCs per year GWP<sub>PFC</sub> = Global warming potential of PFCs 0.001 = Conversion factor from kilograms to tonnes

As the methodology described above may not be practical for a preliminary project, any other methodology for calculating fugitive emissions of  $SF_6$  and PFCs may be used, as long as it is presented to the Ministry with the necessary level of detail and is based on credible and verifiable references and assumptions.

## 1.18 Fugitive GHG Emissions from Refrigeration or Air Conditioning Equipment Use

The fluids used in refrigeration or air conditioning equipment are gases with global warming potentials that can be 2,000 to 15,000 times higher than that of CO<sub>2</sub>. These gases, the most well-known families of which are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) or a mixture of these substances, present problems due to leakage into the atmosphere in the form of fugitive emissions. The Regulation respecting halocarbons (Q-2, r. 29), which regulates emissions of halocarbons into the atmosphere, is intended to protect the ozone layer and minimize the enhancement of the greenhouse effect<sup>28</sup>.

To evaluate annual GHG emissions attributable to the use of refrigeration or air conditioning equipment, Equation 9 can be used by considering each GHG (i) and their addition.

#### Equation 9: GHG Emissions from Refrigeration and Air Conditioning Equipment Use

$$E_{GHG\_Ref} = \frac{\left[(Q_n \times k) + (C \times X \times A) + (Q_n \times Y \times (1 - Z))\right]}{100} \times GWP_i \times 0.001$$

Where:

 $E_{GHG_Refr}$  = GHG emissions attributable to the use of refrigeration equipment, in tonnes of CO<sub>2</sub> equivalent per year

Q<sub>n</sub> = Amount of refrigerant added to new equipment, in kilograms\*

k = Initial emissions (%)\*

C = Total capacity of equipment, in kilograms

X = Annual operating emissions (%)

A = Number of years in operation\*\*

Y = Initial load remaining (%)\*\*\*

Z = Recovery efficiency (%)\*\*\*

<sup>&</sup>lt;sup>28</sup> https://www.legisquebec.gouv.qc.ca/en/document/cr/Q-2,%20r.%2029.

 $GWP_i$  = Global warming potential of refrigerant *i* (refer to Table 3 of this document for the different GWPs to be used)

0.001 = Conversion factor from kilograms to tonnes

\* To be omitted if no equipment has been installed or if equipment has been pre-filled by the manufacturer.

\*\* A = 1, since emissions are calculated on an annual basis.

\*\*\* Omit if no equipment was retired during the year.

systems.					
Table 16. Refrigeration and Air	r Condition	ing Syster	n Loads and	d Emission I	Factors
Application Type	Q <sub>n</sub> (kg)	k (% of initial load)	X (% of initial load/year)	Y (% of initial load)	Z (%)
Domestic Refrigeration	0.05 to 0.5	0.2 to 1%	0.1 to 0.5 %	0 to 80%	0 to 70%
Independent Commercial Applications	0.2 to 6	0.5 to 3%	1 to 15%	0 to 80%	0 to 70%
Commercial Refrigeration, Medium and Large Industry	50 to 2,000	0.5 to 3%	10 to 35%	0 to 100%	0 to 70%
Industrial Refrigeration, Including Food Processing and Cold Storage	10 to 10,000	0.5 to 3%	7 to 25%	50 to 100%	0 to 90%
Cooling	10 to 2,000	0.2 to 1%	2 to 15%	80 to 100%	0 to 95%

Table 16 is used to estimate load, lifespan, and emission factors for refrigeration and air conditioning systems.

Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3: Industrial Processes and Product Use, Table 7.9.

0.2 to 1%

1 to 10%

0 to 80%

0 to 80%

0.5 to 100

## **1.19 Deforestation**

Systems

Commercial and Residential Air

Conditioning, Including Heat Pump

Deforestation activities can have significant impacts on climate change, which are documented by the IPCC and other experts under the term "land-use change." The forestry sector has the capacity to sequester atmospheric carbon in biomass and therefore reduce its concentration in the atmosphere. The scientific literature suggests that forest ecosystems are carbon reservoirs, and that certain space-intensive projects (e.g., road construction, mine operation, landfill construction, or hydrocarbon development) can affect these reservoirs.

If deforestation activities are carried out (usually during the construction phase), the GHG emissions attributable to these activities must be calculated. If deforestation activities are planned for other phases of the project, they should also be taken into account.

#### 1.19.1 GHG Emissions from Forest Land Carbon Stock Loss

To calculate GHG emissions from deforestation, it is recommended to refer to the IPCC document "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture, Forestry and Other Land Use"<sup>29</sup>. These emissions can be calculated by balancing the amount of carbon in a carbon reservoir before and after the project using Equation 10.

#### Equation 10: CO<sub>2</sub> emissions from the loss of forest land carbon stocks.

GHG Emissions (tonnes<sub>CO2</sub>) = 
$$N_H \times t_{DMh} \times (1 + T_x) \times CC \times \frac{44}{12}$$

Where:

TonnesCO<sub>2</sub> = CO<sub>2</sub> emissions due to loss of carbon stocks from deforestation, expressed in tonnes  $N_H$  = Number of hectares deforested  $t_{DMh}$  = Tonnes of dry matter per hectare

 $T_x$  = Ratio of below-ground biomass to above-ground biomass

CC = Carbon content of wood, expressed in tonnes of carbon per tonne of dry matter

44/12 = Molecular weight ratio of CO<sub>2</sub> to carbon

Table 17. Equati	on 10 parameters for determining CO <sub>2</sub> emissions from deforestation activities						
Parameter	IPCC reference						
tомh	Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,						
	Volume 4: Agriculture, Forestry and Other Land Use. Table 4.7.						
Tx	Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,						
	Volume 4: Agriculture, Forestry and Other Land Use. Table 4.4.						
CC	Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,						
	Volume 4: Agriculture, Forestry and Other Land Use. Default value = 0.47.						

Given the particularities of each project and since it is impossible to present all of them in this guide, Table *17* provides suggested references for determining the values of the variables in Equation 10.

GHG emissions from fuel consumption by stationary or mobile equipment used in deforestation activities are to be calculated using the methodologies presented in <u>sections 1.9 and 1.10</u> on stationary and mobile combustion systems.

In addition, when applicable, GHG emissions (or reductions) due to the use of cut wood or the decomposition of logging residues left on the site should be calculated. Any recognized methodology, based on credible and verifiable assumptions, may be used to estimate these emissions (or reductions).

### 1.19.2 Loss of Carbon Sequestration Capacity due to Deforestation

As mentioned in the previous section, deforestation releases a significant amount of CO<sub>2</sub> into the atmosphere. However, this is not the only environmental impact in terms of climate change. Deforestation is also responsible for a net loss of CO<sub>2</sub> sequestration capacity.

<sup>&</sup>lt;sup>29</sup> 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

The net loss of CO<sub>2</sub> sequestration capacity over a certain time period can be calculated with Equation 11Equation 11. If the information regarding the number of years to be considered is missing or too scarce, it is recommended to calculate the loss of carbon sequestration capacity over a period of 100 years. For example, if the reforestation of the destroyed area is planned, it would be acceptable to use the duration of the project.

#### Equation 11: Net loss of CO<sub>2</sub> sequestration for a determined number of years

$$L_{SEQ} = N_H \times GAB \times (1 + T_X) \times CC \times 44/12 \times N_A$$

Where:

 $L_{SEQ}$  = Loss of CO<sub>2</sub> sequestration capacity over a 100-year period, in tonnes of CO<sub>2</sub> N<sub>H</sub> = Number of hectares deforested GAB = Annual growth rate of above-ground biomass, in tonnes of dry matter per hectare per year

*T<sub>x</sub>* = Ratio of below-ground biomass to above-ground biomass

CC = Carbon content of wood, expressed in tonnes of carbon per tonne of dry matter

44/12 = Molecular weight ratio of CO<sub>2</sub> to carbon

N<sub>A</sub> = Number of years considered to assess the net loss of sequestration

Table 18. Equation 11 parameters for determining CO <sub>2</sub> emissions from				
	deforestation activities			
Parameter	IPCC reference			
CBA	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4. Chapter			
	4: Forest Land. Table 4.9.			
Tx	Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,			
	Volume 4: Agriculture, Forestry and Other Land Use. Table 4.4.			
CC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4. Chapter			
	4: Forest Land. Table 4.3			

Table 18 shows the suggested references for estimating the parameter values in Equation 11.

## 1.20 Forests and Their Role in Climate Change Mitigation

The world's forests cover 4 billion hectares, or 31% of the land surface. They contain 60 to 75% of the carbon of continental plant biomass. This represents nearly 860 gigatonnes of carbon (GtC), or nearly 3,150 gigatonnes of CO<sub>2</sub> (GtCO<sub>2</sub>), a stock equivalent to that of the CO<sub>2</sub> in the atmosphere<sup>30</sup>.

CO<sub>2</sub> absorption by photosynthesis is estimated at 220 GtCO<sub>2</sub>/year. At the ecosystem scale, this uptake is largely offset by a reverse flow of CO<sub>2</sub> related not only to the energy expenditure of plant metabolism and growth, but also to the transformation and decomposition of dead organic matter in litter and soil<sup>31</sup>. Wood harvesting and natural disturbances (fires, insect pests, extreme temperatures, etc.) also contribute to this

<sup>&</sup>lt;sup>30</sup> Roux A. (2020). Filière forêt-bois et atténuation du changement climatique : entre séquestration du carbone en forêt et développement de la bioéconomie. Versailles, Éditions Quæ, 170 p.

<sup>&</sup>lt;sup>31</sup> Gough C.M., 2011. Terrestrial Primary Production: Fuel for Life. Nature Education Knowledge, 3 (10), 28.

outward flow due to induced plant mortality. On a global scale, the difference between CO<sub>2</sub> inflow and outflow remains positive, making forest ecosystems net carbon sinks.

Forests play three essential roles in climate change mitigation.

- Carbon reservoir role: this involves storing carbon in vegetation, forest soils, as well as wood products
- Sink role: photosynthesis increases carbon stocks in the forest reservoir by removing carbon dioxide from the atmosphere
- Reduction of fossil fuel emissions: the use of wood products as substitutes for other materials (cement, steel, etc.) and the use of wood for energy production allow significant avoidance of fossilfuel GHG emissions.

Forest management practices can be implemented to promote carbon storage in forests. Stand aging is one option to consider. Other solutions take into account the potential for additional carbon storage through nature-based solutions<sup>32</sup> of afforestation or reforestation using local species. In addition to the carbon storage benefit, the objective here is also to increase the availability of wood resources for downstream user sectors, in order to reduce the pressure on natural or semi-natural forest resources.



### Figure 3. Forests and their Role in Climate Change

Improving forest management and land use reduces the vulnerability of forests and contributes to the mitigation of GHG emissions. As for the role of forests in climate change mitigation, it is inseparable from its role in climate change adaptation since their mitigation capacity depends on their health and the maintenance of their various ecological functions. This is why fostering the resilience of forests is a key issue for the success of GHG emissions mitigation in connection with forestry projects. Conversely, only mitigated climate change will allow forest adaptation strategies to succeed.

<sup>&</sup>lt;sup>32</sup> Nature-based solutions are defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature."

There are several measures that can increase carbon storage in forests and wood products, including:

- Application of sustainable forest management practices
- Longer rotations
- Increasing the area covered by forests
- Rehabilitation of degraded or damaged forests
- Processing harvested wood into long-lasting products
- Use of wood as a renewable energy source.

In short, to mitigate climate change, forests must sequester and store carbon. Increasing wood harvesting decreases the rate of sequestration but promotes storage in wood products and substitution of fossil fuels or materials whose production emits more GHGs. Therefore, in order to optimize climate change mitigation, forest management must promote effective complementarity between sequestration, storage, and substitution mechanisms.

Our two main scenarios (maximizing forest carbon storage or maximizing wood product harvesting) contribute to climate change mitigation by prioritizing different levers. In the scenario with reduced harvest, the lever to prioritise is increasing annual storage in the forest ecosystem that does not favor either carbon storage in wood products or substitution effect. There are indications that this strategy may have some limits due to the decline in the forest's storage capacity as stands age. On the contrary, the scenario of harvest intensification relies more on the effects of substitution to compensate a lesser storage in forests, with a preponderant place given to the substitution of materials with a strong carbon footprint. However, this last aspect comes with the greatest uncertainties, as the substitution coefficients and their evolution in time would be particularly tricky to grasp or anticipate with precision.

Consequently, there is a high level of uncertainty regarding both the carbon sequestration mechanisms and the reductions of fossil-fuel emissions due to the use of wood products (substitution). Some studies show that an increase in harvesting would reduce sequestration in forests by 2050. However, this decrease in the rate of sequestration associated with increased harvesting could be offset over time by the benefits of increased wood use, due to the increased carbon storage in wood products coupled with material and energy substitution effects. However, the results of these studies, which extend up to the year 2050, do not fully agree on the temporal dynamics and magnitude of these mechanisms, and it is difficult to make a definitive decision on how the counterbalancing between the mechanisms favors one management strategy or the other (Roux A. 2020). There is a consensus that more studies are needed to provide key information on the complementarity between sequestration, storage and substitution mechanisms to determine the optimal mix of strategies for forest management.

## 1.21 Loss of wetlands

This section concerns all activities that may affect wetlands. Whether they be ponds, marshes, swamps or peatlands, wetlands are ecosystems that play a major role in sustaining life. The ecological services they provide to society are an asset to our quality of life. For example, some wetlands contribute to GHG emissions mitigation since they function as important carbon sinks, accumulating as much if not more carbon than

forests<sup>33</sup>. Therefore, the loss of wetlands can release significant amounts of greenhouse gases into the atmosphere, which needs to be quantified.

In wetlands, the main carbon stocks are biomass and soil. Biomass is a significant carbon stock, but only in forested wetlands (treed swamps and forested peatlands). In these types of wetlands, emissions associated with the loss of woody biomass (deforestation) must be considered and can be quantified using the method proposed in <u>section 1.19.1</u>.

Soil carbon losses must be quantified for all types of wetlands. Draining a wetland, excavating or reworking the soil causes oxygenation of the soil, which generally results in accelerated decomposition of organic matter, and therefore, CO<sub>2</sub> and N<sub>2</sub>O emissions. By default, it is assumed that all carbon contained in the excavated wetland soil is instantly oxidized and emitted into the atmosphere.

Regarding N<sub>2</sub>O emissions from wetland drainage, we do not have enough data to be able to determine the GHG emissions with certainty. The factors used to calculate the emissions of this gas are expected to evolve with future research. Indeed, measurements of N<sub>2</sub>O emissions will need to be carried out for different types of wetlands in Quebec and, in future versions of this Guide, those factors will be added when available. As for CH<sub>4</sub> emissions, they are considered negligible<sup>34</sup>.

Consequently, the GHG emissions calculations presented in this section only consider CO<sub>2</sub> emissions resulting from wetland loss. These emissions can be calculated with Equation 12.

#### Equation 12: CO<sub>2</sub> Emissions from Wetland Loss

$$E_{CO2} = \sum_{i=1}^{i=n} \left( L_{MH_i} \times SC_{MH_i} \times \frac{44}{12} \right)$$

Where:

 $E_{CO2} = CO_2$  emissions attributable to wetland loss, in tonnes of  $CO_2$  $L_{MHi} = Loss$  of wetland type *i*, in hectares  $SC_{MHi} = Carbon$  stock of wetland type *i*, in tonnes of C per hectare 44/12 = Ratio of the molecular mass  $CO_2$  to the molecular mass of C

<sup>&</sup>lt;sup>33</sup> J. Beaulne & al., « Peat Deposits Store More Carbon than Trees in Forested Peatlands of the Boreal Biome », Scientific Reports 11, no 1 (January 29 2021): 2657, https://doi.org/10.1038/s41598-021-82004-x; M. Garneau et S. van Bellen, « Synthèse de la valeur et la répartition du stock de carbone terrestre au Québec », 2016.

<sup>&</sup>lt;sup>34</sup> 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 7. Wetlands. Page 7.5

Table 19. Average Carbon Stock for Each Type of Wetland in Eastern Canada							
Wetland Type	Vegetation Zone	Average soil carbon mass (tonnes/ha)	Source				
Open Bog	Northern Temperate	1 114	MELCCFP and C-Paleo laboratory UQAM, unpublished data <sup>35</sup>				
	Boreal	1 150	Bauer et al. 2024 <sup>36</sup>				
	Arctic Tundra	1 098	Bauer et al. 2024				
Open Fen	Northern Temperate	1 154	MELCCFP and C-Paleo laboratory UQAM, unpublished data				
	Boral	1 132	Bauer et al. 2024				
	Arctic Tundra	219	Bauer et al. 2024				
Wooded Peatland*	Northern Temperate	1 133	MELCCFP and C-Paleo laboratory UQAM, unpublished data				
	Boreal	9 02	Bauer et al. 2024				
Swamp*	All	61	MELCCFP and C-Paleo laboratory UQAM, unpublished data				
Freshwater marsh	All	48	MELCCFP and C-Paleo laboratory UQAM, unpublished data				
Saltwater marsh	All	89	Magnan & al. (2023) <sup>37</sup>				
Pond	All	90	Sanderson & Garneau (2018) <sup>38</sup>				

Table 19 presents the average carbon stocks for each type of wetlands in Quebec.

\*Emissions from deforestation in wetlands must also be considered and can be calculated using the method proposed in section 1.19.1.

This approach is similar to the one presented in the document "Draft technical guide related to the strategic assessment of climate change" produced by Environment and Climate Change Canada in August 2021<sup>39</sup>. However, it is possible to use calculation methods other than those presented in this section. In this case, they must be justified, with supporting references, and based on credible, reasonable, transparent and conservative assumptions.

Finaly, the "Field guide for estimating carbon stocks in wetlands"<sup>40</sup>, published in May 2024 by MELCCFP presents a method for carbon stock quantification in wetlands with the use of simple field measurements. This method was developed for non-permafrost wetlands in temperate and boreal regions.

<sup>&</sup>lt;sup>35</sup> MELCCFP et Laboratoire C-Paleo UQAM. 2024. Données non publiées. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP), Direction des milieux humides et Université du Québec à Montréal (UQAM), Laboratoire C-Paleo de Michelle Garneau.

<sup>&</sup>lt;sup>36</sup> I.E. Bauer et al., « Peat Profile Database from Peatlands in Canada », *Ecology* 105, nº 10 (2024): e4398, https://doi.org/10.1002/ecy.4398.

<sup>&</sup>lt;sup>37</sup> Magnan, G., Garneau, M., Beaulne, J., Lavoie, M., Pellerin, S., Perrier, L., Richard, P., Sanderson, N. A simple field method for estimating the mass of organic carbon stored in undisturbed wetland soils. Mires and Peat, Volume 29 (2023), Article 08, 13 pp., <u>http://www.mires-and-peat.net/</u>, ISSN 1819-754X. International Mire Conservation Group and International Peatland Society. DOI: 10.19189/MaP.2022.SNPG.Sc. 1818931

<sup>&</sup>lt;sup>38</sup> Nicole Sanderson et Michelle Garneau, « Estimation préliminaire des puits et flux de carbone dans les milieux humides du Québec », 2018. Rapport final présenté au Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques. 31 pp. + annexe.

<sup>&</sup>lt;sup>39</sup> https://www.canada.ca/fr/environnement-changement-climatique/organisation/transparence/consultations/version-preliminaire-guide-technique-relatifevaluation-strategique-changements-climatiques.html

<sup>&</sup>lt;sup>40</sup> https://www.environnement.gouv.qc.ca/eau/rives/guide-inventaire-estimation-carbone-milieux-humides.pdf

## **1.22 Wetland Conservation**

In Quebec, wetlands cover approximately 18 million hectares<sup>41</sup>, or about 11% of the province's total land area. Whether they be ponds, marshes, swamps or peatlands, wetlands represent the essential links in the web of natural environments in Quebec. These ecosystems are defined by sites saturated with water or flooded for a sufficiently long period of time to influence the nature of the soil or the composition of the vegetation.

The conservation of wetlands and bodies of water, which includes in particular their restoration, is at the heart of the Ministry's mission, since they fulfill essential ecological functions and constitute a vital link in Quebec's biodiversity. Thus, the Ministry's legal and regulatory framework reflects the importance of this issue and provides various measures to curb the loss of these environments and to increase gains in this area.

Wetlands play an important role in the global carbon balance, both in terms of their carbon storage capacity and their potential to release stored carbon due to drainage, drought, or rising temperatures. While they cover only about 3% of the earth's surface, they store one third of the world's soil carbon, or about 445 billion tonnes<sup>42</sup>. Carbon accumulation is very slow in these environments, but when they are drained, they can quickly release significant amounts of carbon dioxide.

In many wetlands, carbon gradually accumulates in vegetation, and then in the soil over a long period of time. Peatlands in particular are able to sequester and store carbon in the soil over thousands of years, contrary to other ecosystems such as forests, which reach a saturation point after a certain period of time or are subject to periodic disturbances. However, wetland loss interrupts their ability to sequester CO<sub>2</sub> and store carbon.

Despite the ecological and climatic importance of wetlands, their drainage and conversion has been commonplace around the world. Several human activities can lead to wetland drainage, including:

- Peatland harvesting
- Agricultural activities
- Real estate developments
- Planting of woody species
- Mining development
- Road structures construction producing discontinuities that affect the wetland.

Restoring degraded wetlands can provide benefits on two levels:

- Slowing down carbon stock decomposition and loss, which reduces CO<sub>2</sub> emissions to the atmosphere
- Restoring their long-term carbon sequestration function.

## **1.23 GHG Emissions from Ecosystem Flooding**

Flooded lands are defined as bodies of water regulated by human activities, such as power generation, irrigation, navigation, or recreation, and where the regulation of water results in substantial changes in water

<sup>&</sup>lt;sup>41</sup> MELCCFP. These data come from an inventory carried out by the Ministry in 2019 using an updated methodology and recent cartographic sources.

<sup>&</sup>lt;sup>42</sup> Wang, H., Richardson, C.J., & Ho. M. (2015). Dual controls on carbon loss during drought in peatlands. Nature Climate Change 5(6): 584-7.

area. Regulated lakes and rivers, where the primary ecosystem prior to flooding was a natural lake or river, are not considered flooded lands. This type of emissions is most common in projects involving flooding (e.g., dam construction).

GHG emissions from flooded lands are generated by two main mechanisms (in cold regions, CO<sub>2</sub> and CH<sub>4</sub> accumulate under the ice and are emitted during thawing):

- Molecular diffusion of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O between air and water
- CH<sub>4</sub> bubbles from sediments in the water column (bubble emissions).

In its document "Good Practice Guidance for Land Use, Land-Use Change and Forestry,"<sup>43</sup> the IPCC proposes three methodological tiers for estimating emissions from ecosystem flooding, with an increasing degree of precision.

The proposed methodology for estimating GHG emissions from ecosystem flooding is Tier 1. This is a simplified methodology based on default emissions data and aggregate area data. However, Tier 2 and Tier 3 methods can also be used, which are more comprehensive and may include additional country-, province-, or region-specific data.

The calculation formulas are different for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions. They are presented separately below.

## 1.23.1 CO<sub>2</sub> Emissions from Ecosystem Flooding

CO<sub>2</sub> emissions from ecosystem flooding are considered biogenic and should be accounted for separately from other GHG emissions. The estimation method to be applied is based on the change in carbon stocks resulting from conversion to flooded land and assumes that pre-conversion stocks are lost in the first year after conversion.

The annual change in carbon stocks of living biomass on land converted to flooded land can be calculated with Equation 13.

Equation 13: Change in Carbon Stocks of Living Biomass from Land Converted to Flooded Land

$$\Delta C_{Tflood} = \left[\sum S_i \times \left(B_{After} - B_{Before}\right)_i\right] \times CF$$

Where:

 $\Delta C_{Tflood}$  = Change in living biomass carbon stocks of land converted to flooded land, in tonnes of C  $S_i$  = Surface area of land converted annually to flooded land from initial use *i*, in hectares

 $B_{before}$  = Living biomass of land before conversion to flooded land, in tonnes of dry matter per hectare  $B_{after}$  = Living biomass after conversion to flooded land, in tonnes of dry matter per hectare (default value = 0)

CF = Carbon fraction of dry matter (default value = 0.5)

<sup>&</sup>lt;sup>43</sup> https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/GPG\_LULUCF\_FULL.pdf

For <u>forest</u> land converted to flooded land, the living biomass present prior to conversion can be calculated using Equation 14.

#### Equation 14: Living Biomass Before Conversion of Forest Land to Flooded Land

$$B_{Before} = t_{DMh} \times (1 + T_x)$$

Where:

 $B_{before}$  = Living biomass of land before conversion to flooded land, in tonnes of dry matter per hectare  $t_{DMh}$  = Tonnes of dry matter per hectare

 $T_x$  = Ratio of below-ground biomass to above-ground biomass

The values of the parameters  $t_{MSh}$  and  $T_x$  are detailed in Table 17.

Subsequently, CO<sub>2</sub> emissions from forest land flooding can be determined with Equation 15.

Equation 15: CO<sub>2</sub> Emissions from Forest Land Flooding

$$E_{CO2\_TFflood} = \Delta C_{Tflood} \times \frac{44}{12}$$

Where:

 $E_{CO2_T flood}$  = CO<sub>2</sub> emissions attributable to flooding of forest land, in tonnes of CO<sub>2</sub>

 $\Delta C_{Tflood}$  = Annual change in living biomass carbon stocks of forest land converted to flooded land, in tonnes of C

44/12 = Molecular weight ratio of CO<sub>2</sub> to carbon

CO<sub>2</sub> sequestration capacity loss due to flooding of forest land can be calculated using the equations presented in <u>Section 1.19.2.</u>

Finally, for <u>wildlands</u> converted to flooded land, Table 20 associates default baseline values with organic carbon stocks for different soil types with natural vegetation.

Table 20. Default baseline values associated with soil organic carbon stocks (COS <sub>REF</sub> ) under natural vegetation							
(Tonnes of carbo	n per hecta	are at a dep	<u>th of 0 to 30</u>	centimetre	s)		
Region (*likely to be present in Quebec)	Highly active clay soils	Low- activity clay soils	Sandy soils	Spodic soils	Volcanic soils	Wetland soils	
Boreal*	68	N/A	10	117	20	146	
Cold temperate and dry*	50	33	34	N/A	20	87	
Cold temperate and humid*	95	85	71	115	130	87	
Warm temperate and dry	38	24	19	N/A	70	88	
Hot temperate and humid	88	63	34	N/A	50	88	
Tropical and dry	38	35	31	N/A	50	86	
Tropical and humid	65	47	39	N/A	70	86	
Tropical and rainy	44	60	66	N/A	130	86	

Table 20. Default baseline values associated with soil organic carbon stocks						
(COS <sub>REF</sub> ) under natural vegetation						
(Tonnes of carbon per hectare at a depth of 0 to 30 centimetres)						
Region	Highly	Low-	Sandy soils	Spodic	Volcanic	Wetland
(*likely to be present in Quebec)	active	activity		soils	soils	soils
	clay soils	clay soils				

Source: IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry. Table 3.3.3. https://www.ipccnggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/GPG\_LULUCF\_FULL.pdf

Using the soil organic carbon stock value obtained from Table 20, Equation 16 estimates CO<sub>2</sub> emissions from <u>wildlands</u> flooding.

#### Equation 16: CO<sub>2</sub> Emissions from Wildlands Flooding

$$E_{CO2_{T}\_WL\_flood} = S_i \times SOC_{REF} \times \frac{44}{12}$$

Where:

 $E_{CO2T\_WL\_flood}$  = CO<sub>2</sub> emissions attributable to flooding of wildlands, in tonnes of CO<sub>2</sub>

S<sub>i</sub> = Surface area of land converted annually to flooded land from the initial use i, in hectares

SOC<sub>REF</sub> = Soil organic carbon stocks

44/12 = Molecular weight ratio of CO<sub>2</sub> to carbon

#### 1.23.2 CH<sub>4</sub> Emissions from Ecosystem Flooding

The Tier 1 method for estimating CH<sub>4</sub> emissions from land flooding accounts for molecular diffusion and bubbling emissions of CH<sub>4</sub> from sediments. These emissions, expressed in tonnes of CH<sub>4</sub> per year, can be estimated with Equation 17.

#### Equation 17: CH<sub>4</sub> Emissions from Ecosystem Flooding

$$CH_4 \ emissions = (ECH4_{diff} + ECH4_{bubbles}) \times P \times Sur_{flooded} \times 0.001$$

Where:

*ECH4<sub>diff</sub>* = Average CH<sub>4</sub> emission factor per release, expressed in kilograms of CH<sub>4</sub> per hectare per day

*ECH4*<sub>bubbles</sub> = Average CH<sub>4</sub> emission factor per bubble, expressed in kilograms of CH<sub>4</sub> per hectare per day

*P* = *Period, expressed in days (usually 365 for annual emissions estimation)* 

*Sur*<sub>flooded</sub> = *Total* flooded surface area, expressed in hectares

0.001 = Conversion factor from kilograms to tonnes

Table 21	shows the	average CH4	emission	factors f	for molecula	r diffusior	and b	oubbles fro	om sediment.
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Table 21 Average CH₄ Emission Factors of Reservoirs				
	Average CH₄ Emission Factors, in kg CH₄ x ha⁻¹ x day⁻¹			
	CH4 <sub>diff</sub>	CH4 <sub>bubbles</sub>		
Reservoir in boreal region	0.11	0.29		
Reservoir in temperate region	0.20	0.14		

Source: IPCC. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Appendix 3a.3 Wetlands remaining Wetlands: Basis for future methodological development. Table 3A.3.5 Default Emissions Factors for Reservoirs. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/Chp3/App\_3a3\_Wetlands.pdf

## 1.23.3 N<sub>2</sub>O emissions from flooded ecosystems

The Tier 1 method for estimating N<sub>2</sub>O emissions from flooded lands considers only molecular diffusion emissions, since bubble emissions are not significant. These emissions, expressed in tonnes of N<sub>2</sub>O per year, can be estimated with Equation 18<sup>44</sup>.

#### Equation 18: N<sub>2</sub>O emissions from ecosystem flooding

$$N_2O \ emissions = P \times EN_2O_{diff} \times Sur_{flooded} \times 0.001$$

Where:

 $EN_2O_{diff}$  = Average N<sub>2</sub>O emission factor per diffusion, expressed in kilograms of N<sub>2</sub>O per hectare per day

*P* = Time period, expressed in days (usually 365 for annual emissions estimation)

*Sur<sub>flooded</sub>* = Total flooded surface area, expressed in hectares

0.001 = Conversion factor from kilograms to tonnes

Table 22 shows the average N<sub>2</sub>O emission factors for reservoirs.

Table 22. Average N <sub>2</sub> O Emission Factors for Reservoirs					
	Average N <sub>2</sub> O emission factors, in kg N <sub>2</sub> O x ha <sup>-1</sup> x day <sup>-1</sup>				
Reservoir in boreal region	0.008				
Reservoir in temperate region	Not measured (depending on the specific project characteristics)				

Source: IPCC. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Table 3A.3.5 Default Emissions Factors for Reservoirs. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/GPG\_LULUCF\_FULL.pdf

<sup>&</sup>lt;sup>44</sup> Source: IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry. Equation 3A.3.10 N<sub>2</sub>O Emissions from flooded lands. http://www.ipccnggip.iges.or.jp/public/gpglulucf/gpglulucf\_files/GPG\_LULUCF\_FULL.pdf.

## **1.24 GHG Emissions from Livestock and Agricultural Projects**

Two methodologies are suggested for calculating GHG emissions from animal production projects. Calculations can be performed using either:

- a) the latest update of the Holos agricultural farm GHG emissions assessment and reduction software, Section 1.24.1; or
- b) the equations presented in section 1.24.2.

The agricultural community is generally familiar with the Holos software, so this option was evaluated and considered in this guide.

### 1.24.1 Calculations with the Holos Software

The Holos software<sup>45</sup> was developed by Agriculture and Agri-Food Canada to estimate GHG emissions from agricultural operations. The algorithms used by the software are based on the methods proposed by the IPCC but adapted to Canadian conditions. Holos estimates GHG emissions from enteric fermentation, animal waste management, and crop production. It also estimates emissions related to energy use during farm operations. Thus, for agricultural projects, GHG emissions from stationary and mobile combustion sources and electricity use can be estimated directly from the software or using the equations in Sections 3.1 and 3.2.

However, the Holos software is not designed to estimate GHG emissions during the construction phase. Therefore, these emissions must be calculated using the applicable formulas presented in this guide.

### 1.24.2 Calculation Using Equations (without the Holos software)

Enteric fermentation, agricultural soil management, and manure management account for about 75% of the emissions, or respectively for 40%, 27.99%, and 27.3% of the total emissions from the livestock production sector. However, each type of livestock production has differences that must be accounted for in the calculations. The next sections present the different emission sources and types of greenhouse gases to be considered:

- CH<sub>4</sub> emissions from enteric fermentation
- CH<sub>4</sub> emissions from manure storage and processing
- N<sub>2</sub>O emissions from manure storage and processing
- N<sub>2</sub>O emissions from manure application
- N<sub>2</sub>O emissions from fertilizer and crop residue application.

### 1.24.2.1 CH<sub>4</sub> Emissions from Enteric Fermentation

CH<sub>4</sub> is produced by enteric fermentation during the normal digestion process of herbivores. CH<sub>4</sub> emissions from livestock production can be estimated from Equation 19.

<sup>&</sup>lt;sup>45</sup> https://agriculture.canada.ca/en/agricultural-science-and-innovation/agricultural-research-results/holos-software-program.

Equation 19: Methane Emissions from Enteric Fermentation

$$E_{CH4\_EF} = \sum_{i=1}^{i=k} N_i \times f_{CH4\_EF_i} \times 0.001$$

Where:

*E*<sub>CH4\_EF</sub> = Annual CH<sub>4</sub> emissions from enteric fermentation, in tonnes of CH<sub>4</sub> per year

*i* = Animal category

 $N_i$  = Number of heads of animal category  $i^{46}$ 

 $f_{CH4\_EFi}$  = CH<sub>4</sub> emission factor for enteric fermentation associated with animal category i, in kg CH<sub>4</sub>/head/year

0.001 = Conversion factor from kilograms to tonnes

Table 23. CH₄ Emission Factors Associated with Enteric Fermentation				
Animal Category	CH₄ Emission Factor (kg CH₄/head/year)	Reference		
Dairy cows	145.8	National Inventory Report (NIR) 1990-		
Dairy heifers	76.7	2022. Part II. Table A6.4-1.		
Bulls	123.2			
Beef cows	120.7			
Beef heifers	91.4			
Heifers for slaughter	54.6			
Steers	49.9			
Calves	43.9			
Bison	55	National Inventory Report (NIR) 1990-		
Sheep	8	2022. Part II. Table A6.4-2.		
Lambs	8			
Goats	5			
Horses	18			
Mules and donkeys	10			
Swine:				
Boars	1.5			
Sows	1.5			
Pigs < 20 kg	1.5			
Pigs 20-60 kg	1.5			
Pigs > 60 kg	1.5			
Llamas and alpacas	8			
Elk and deer	20			
Wild boars	1.5			
Foxes	ND			
Mink	ND			
Rabbits	ND			

<sup>&</sup>lt;sup>46</sup> Note: the number of heads applies to a single type of animal and differs from the number of animal units, which takes into account all types of animals reduced to a common denominator. Examples: 1 dairy cow = 1 animal unit; 1 laying hen = 175 animal units. Source: Regulation respecting the environmental impact assessment and review of certain projects.

Chickens	ND
Chickens	ND
Turkeys	ND

1.24.2.2 CH<sub>4</sub> Emissions from Manure Storage and Processing

Equation 20 is used to calculate CH<sub>4</sub> emissions from manure storage and processing.

Equation 20: CH<sub>4</sub> Emissions from Manure Storage and Processing

$$E_{CH4\_MS} = \sum_{i=1}^{i=k} N_i \times f_{CH4\_MS_i} \times 0.001$$

Where:

*E*<sub>CH4\_MS</sub> = Annual CH<sub>4</sub> emissions from manure storage and processing, in tonnes of CH<sub>4</sub> per year

i = Animal category

 $N_i$  = Number of heads of animal category I

 $f_{CH4\_MSi}$  = CH<sub>4</sub> emission factor associated with manure storage and processing of animal category *i*, *in* kg CH<sub>4</sub>/head/year

0.001 = Conversion factor from kilograms to tonnes.

CH<sub>4</sub> emissions from manure storage and processing can be estimated from the emission factors presented in Table 24.

Table 24. CH₄ Emission Factors Associated with Manure Storage and Processing				
Animal Category	CH₄ Emission Factor (kg CH₄/head/year)	Reference		
Dairy cows	40.0	Adapted from the National Inventory Report		
Dairy heifers	17.0	(NIR) 1990-2022. Part II. Tables A6.4-6,		
Bulls	4.7	A6.4-7 and A6.4-8		
Beef cows	4.5			
Beef heifers	3.2			
Steers	2.0			
Heifers for slaughter	2.2			
Calves	2.9			
Pigs < 20 kg	2.2			
Pigs 20-60 kg	4.2			
Pigs > 60 kg	9.4			
Boars	7.0			
Sows	7.0			
Sheep	0.33			
Lambs	0.22			
Goats	0.32			
Horses	2.6			
Bison	2.1			
Elk and deer	0.22			
Wild boars	0.56			

Foxes	0.68
Mink	0.68
Rabbits	0.08
Mules and asses	0.76
Chickens	0.03
Hens	0.11
Turkeys	0.10

#### 1.24.2.3 N<sub>2</sub>O Emissions from Manure Storage and Processing

N<sub>2</sub>O production during manure storage and processing occurs during nitrification and denitrification of the nitrogen in the manure.

N<sub>2</sub>O emissions from manure storage and processing can be calculated from the N excretion rate, depending on the animal category, and the N<sub>2</sub>O emission factor per kilogram of N, depending on the manure management type. Equation 21 is used to calculate N<sub>2</sub>O emissions from manure storage and processing.

Equation 21: N<sub>2</sub>O Emissions from Manure Storage and Processing

$$E_{N2O\_MS} = \sum_{i=1}^{n} N_i \times T_{exc_{Nitrogen_i}} \times f_{N2O/N} \times 0.001$$

Where:

 $E_{N2O_{MS}} = N_2O$  emissions attributable to manure storage and processing, expressed in tonnes of N<sub>2</sub>O per year

 $N_i$  = Number of heads of animal category i

*T\_exc\_Nitrogen*<sup>*i*</sup> = Annual nitrogen excretion rate from manure for animal category *i*, expressed in kg *N*/head/year

 $f_{N2O/N} = N_2O$  emission factor associated with manure storage and processing, expressed in kilograms of  $N_2O$  per kilogram of nitrogen excreted

0.001 = Conversion factor from kilograms to tonnes

Table 25. Annual Nitrogen Excretion Rate from Manure					
Animal	$kg_N$	Animal	$kg_N$	Animal	$kg_N$
category	head  imes year	category	head  imes year	category	head  imes year
Dairy cows	122	Pigs (20-60 kg)	5.5	Broilers	0.4
Dairy heifers	76	Pigs > 60 kg	13.8	Turkeys	1.8
Bulls	105	Boars	17	Elk and deer	13.6
Beef cows	75	Sheep	4.1	Wild boars	11.1
Beef heifers	57	Lambs	4.1	Foxes	7.9
Heifers ready for	67	Goats	10.5	Mink	3.0
slaughter					
Steers	69	Horses	49.3	Rabbits	4.7
Calves	27	Llamas and	17.2	Mules and	26.8
		alpacas		asses	
Sows	17	Bison	67.7		
Pigs (> 20 kg)	1.3	Hens	0.5		

Table 25 presents the annual nitrogen excretion rate of manure from different categories of farm animals.

Source: National Inventory Report 1990-2022, Part II. Tables A3.4-23, A3.4-24, and A3.4-25

Table 26 shows N<sub>2</sub>O emission factors for animal categories based on manure management practises.

Table 26. N <sub>2</sub> O Emission Factors by Manure Management Approach				
	Manure Storage Systems			
	Liquid Manure Solid and Dry Other System			
	Management Systems	Manure Storage		
kg of N <sub>2</sub> O per kg of nitrogen excreted	0.001	0.02	0.005	

Source: National Inventory Report 1990-2022, Part II. Table A6.4-10.

#### 1.24.2.4 N<sub>2</sub>O Emissions from Manure Application

N<sub>2</sub>O emissions from manure application can be calculated from Equation 22.

#### Equation 22: N<sub>2</sub>O Emissions from Manure Application

$$E_{N2O\_AP} = \sum_{i=1}^{i=n} Q_{MA_i} \times CON_{Nitrogen_{MA_i}} \times EF_{N2O_{MA_i}} \times 0.001$$

Where:

 $E_{N2O\_AP}$  = Annual N<sub>2</sub>O emissions from manure application, expressed in tonnes of N<sub>2</sub>O per year  $Q_{MAi}$  = Tonnes of manure of type i applied in the year

CON\_Nitrogen<sub>MAi</sub> = Nitrogen content of manure for type *i*, expressed in kilograms of nitrogen per tonne of manure

 $EF_N_2O_{MAi} = N_2O$  emission factor associated with manure type *i*, expressed in kilograms of N<sub>2</sub>O per kilogram of manure nitrogen

0.001 = Conversion factor from kilograms to tonnes

For Quebec and Ontario, an N<sub>2</sub>O emission factor of 0.012 kilograms of N<sub>2</sub>O per kilogram of manure nitrogen can be used<sup>47</sup>. The nitrogen content of different types of manure is shown in Table 27.

Table 27. Nitrogen Content of Different Types of Manure and Slurry			
Type of Manure or Slurry	Nitrogen Content (kilograms/tonne)		
Dairy cattle - solid manure	5.7		
Dairy cattle - slurry	3.1		
Beef cattle (intensive farming) - manure	7.1		
Cows and calves - manure	4.8		
Sheep - solid manure	11		
Pigs - fattening, slurry	2.7 to 4.9		
Poultry - chicken manure	28		
Poultry - laying hen manure	31		

Sources: Centre de référence en agriculture agroalimentaire et du Québec (CRAAQ), 2003<sup>48</sup> and 2007<sup>49</sup>; ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), 1997<sup>50</sup>.

1.24.2.5 N<sub>2</sub>O Emissions from Nitrogen Losses Associated with Inorganic and Organic Fertilizer Application and Crop Residue Application

N<sub>2</sub>O emissions from inorganic and organic fertilizers and crop residues application to agricultural soils can be calculated from Equation 23.

Equation 23: N<sub>2</sub>O Emissions from Inorganic and Organic Fertilizers and Crop Residues Application

$$E_{N2O\_Fer} = Q_{Nitrogen} \times EF_{N2O\_N} \times 0.001$$

Where:

 $E_{N2O_Fer}$  = Annual N<sub>2</sub>O emissions from application of inorganic and organic fertilizers and crop residues, in tonnes of N<sub>2</sub>O per year

 $Q_{Nitrogen}$  = Tonnes of nitrogen applied per year  $EF_{N2O_N} = N_2O$  emission factor, in kilograms of N<sub>2</sub>O per tonne of nitrogen applied to soil 0.001 = Conversion factor from kilograms to tonnes

Table 28 presents N<sub>2</sub>O emission factors per tonne of nitrogen associated with fertilizer and crop residue application, in kilograms of N<sub>2</sub>O per tonne of nitrogen.

<sup>&</sup>lt;sup>47</sup> Gregorich, E.G., P. Rochette, A.J. VandenBygaart and D.A. Angers, 2005. *Greenhouse gas contributions of agricultural soils and potential mitigation practices in eastern Canada*. Soil & Tillage Research 76:120.

<sup>&</sup>lt;sup>48</sup> CRAAQ. Guide de référence en fertilisation (Fertilization reference guide), 2003b.

<sup>49</sup> CRAAQ. Caractéristiques des effluents d'élevage – validées – (porc et poule pondeuse), 2007, 7 pages. http://pub.craaq.qc.ca/transit/validees/tdm.pdf.

<sup>&</sup>lt;sup>50</sup> MAPAQ. Guide régional sur la composition des fumiers et lisiers sur les fermes de la Montérégie-Est (Regional guidance on manure and slurry composition for farms in the Montérégie Est region), Bureau des renseignements agricoles de Saint-Hyacinthe, 1997.

Table 28. Annual N <sub>2</sub> O Emission Factor per tonne of Nitrogen from Fertilizer and Crop Residue Application						
Province EF <sub>N20 N</sub> (kg N <sub>2</sub> O per tonne of Nitrogen per year)						
N Organic N Inorganic N Crop Residue						
Alberta	8.3	10	8.3			
British Columbia	8.3	4.8	5.3			
Manitoba	10	10	8.6			
Atlantic Provinces	9	14	11			
Ontario	17	20	17			
Quebec	23	30	23			
Saskatchewan	4.1	6.6	5.7			

Source: National Inventory Report 1990-2022, Part II. Table A6.4-20.

## 1.25 CH<sub>4</sub> Emissions from Landfill

Landfilling of waste materials results in the decomposition of organic matter in the absence of oxygen (anaerobiois) and the generation of biogas, consisting primarily of CH<sub>4</sub> and CO<sub>2</sub>. As mentioned, CO<sub>2</sub> emissions from biomass are considered biogenic (carbon neutral), but CH<sub>4</sub> emissions are not. Most of the emissions are released in the first few years, and the remaining emissions decline over time until after the site is closed. Since CH<sub>4</sub> has a global warming potential 28 times higher than CO<sub>2</sub> and considering the temporal process of emissions, it is important to include mitigation measures in the design of a project.

For the quantification of GHG emissions, it is important to know that:

- CH<sub>4</sub> production at a landfill is dependent on several variables, including the composition of the organic material being landfilled and the temperature and moisture content resulting from precipitation
- CH<sub>4</sub> emissions to the atmosphere will subsequently depend on the efficiency of the landfill's gas capture and destruction system and the rate of oxidation of the emissions by the landfill cell cover
- For landfill expansion, consideration should be given to ongoing and future methane emissions, including those associated with materials landfilled in previously permitted areas
- The time period to be considered for these emissions includes the operational phase and extends beyond the post-closure phase; it is recommended that methane emissions be taken into account for a minimum of 100 years after the site closure.
- The calculation of CH<sub>4</sub> emissions can be performed using either: •
  - a) the US EPA Landfill Gas Emissions Generation Model (LandGEM)
  - b) the equations presented in Section 1.25.2.

### 1.25.1 LandGEM Calculation

The Landfill Gas Emissions Generation Model (LandGEM), which is the latest model developed by the US EPA, can be used to calculate CH<sub>4</sub> emissions from landfilling of waste materials. The information used in the model should be provided in a quantification report. The calculation parameters should be consistent with those in the following section.

#### 1.25.2 Calculation Without the LandGEM Model

CH<sub>4</sub> emissions from waste landfilled for a given year can be estimated with Equation 24Equation 24. These emissions correspond to the quantities generated minus those recovered and those that are oxidized to CO<sub>2</sub>.

Equation 24: CH<sub>4</sub> Emissions from Waste Landfilled

$$ECH_4Landf = \left[\sum CH_4 gen_{x,T} - R_T\right] \times (1 - OX_T)$$

Where:

 $E_{CH4Landf} = CH_4$  emissions in year T, in tonnes of CH<sub>4</sub> per year T = Year x = Type of waste material (e.g., yard waste, paper)  $CH_4 gen_{x,T} = CH_4$  generated from decomposable material x in year T, in tonnes of CH<sub>4</sub> per year  $R_T = CH_4$  recovered in year T, in tonnes of CH<sub>4</sub> per year  $OX_T = Oxidation$  factor in year T, fraction. By default, this factor is 0.1.

The methane generated over the years can be estimated based on the quantities and composition of the waste materials buried in the landfill and the management practices of the site.

As shown in Equation 25Equation 25, the potential for methane generation at landfills is based on the mass of organic carbon that will decompose under anaerobic conditions at the landfill (CODDm), which depends on the following:

- The tonnage and type (x) of waste material that is landfilled annually
- The degradable organic carbon (DOC), which represents the portion of organic carbon in the waste that is available for decomposition and is determined by the composition of the waste entering the landfill
- The fraction of DOC that is likely to decompose under anaerobic conditions (DOCf). The DOCf is an estimate of the amount of DOC in the waste material that actually decomposes in the landfill
- The CH<sub>4</sub> correction factor (CCF), which accounts for the decomposition of the waste under different management practices. The CCF can vary between 0 and 1. 0 corresponds to completely aerobic conditions, while 1 corresponds to completely anaerobic landfill conditions. Quebec uses a CCF of 1 for anaerobic landfills, as recommended in the 2006 IPCC Guidelines.

The methane emissions generated from Equation 24 are the sum of the methane emissions for each of the landfill waste types presented in Table 25.

Equation 25: Calculation of Degradable and Decomposable Organic Carbon (DDOCm)<sup>51</sup>

$$DDOCm_{x,T} = WM_{x,T} \times DOC_x \times DOC_{fx} \times MCF$$

Where:

 $DDOCm_{x,T}$  = Mass of degradable and decomposable organic carbon from material x deposited in year *T* (in tonnes)

x = Type of waste material deposited (e.g., food waste, paper) or sector (residential, CRD, IC&I) T = Year

*WM<sub>x,T</sub>* = *Mass of waste material x deposited in year T (in tonnes)* 

DOC<sub>x</sub> = Degradable organic carbon in waste material type x

DOC<sub>fx</sub> = Fraction of DOC that is likely to or does decompose for waste material type x

MCF = CH<sub>4</sub> correction factor for aerobic decomposition in the landfill year, fraction. The default is 1.

The basis for calculating CH<sub>4</sub> emissions is a first-order decomposition model based on an exponential factor that describes the fraction of degradable material that decomposes into CH<sub>4</sub> and CO<sub>2</sub> each year. Equation 29 and Equation 30 are used to calculate, for a given year, the amount of degradable and decomposable organic carbon accumulated and decomposed by waste material type.

Equation 26: Calculation of Accumulated DDOCm<sup>52</sup>

$$DDOCma_{x,T} = DDOCmd_{x,T} + (DDOCma_{x,T-1} \times e^{-k_x})$$

Equation 27: Calculation of Decomposed DDOCm<sup>53</sup>

 $DDOCm \ decomp_{x,T} = DDOCma_{x,T-1} \times (1 - e^{-k_x})$ 

Where:

T = Year

 $DDOCma_{x,T} = DDOCmx$  accumulated in the landfill at the end of year T, in tonnes  $DDOCmd_{x,T} = DDOCmx$  deposited in the landfill during year T, in tonnes  $DDOCma_{x,T-1} = DDOCmx$  accumulated in the landfill at the end of year (T-1), in tonnes DDOCm decomp<sub>x,T</sub> = DDOCmx decomposed in the landfill during year T, in tonnes  $k_x$  = Reaction constant of material x  $t_{1/2}$  = Half-life time (in years)

 $k = \ln(2)/t_{1/2}$ 

Equation 28 calculates CH<sub>4</sub> emissions from landfilled waste as a function of the degradable and decomposable organic carbon in material x.

<sup>&</sup>lt;sup>51</sup> 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 3, Equation 3.2.

<sup>&</sup>lt;sup>52</sup> Modified from Equation 3.5 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 3.

<sup>&</sup>lt;sup>53</sup> Modified from Equation 3.5 of the 2006 IPCC Guidelines. for National Greenhouse Gas Inventories, Volume 5, Chapter 3.

Equation 28: CH₄ Emissions from Landfilled Waste as a Function of Degradable and Decomposable Organic Carbon<sup>54</sup>

$$CH_4 gen_{x,T} = DDOCm decomp_{x,T} \times F \times 16/12$$

Where:

 $CH_4$  gen<sub>x,T</sub> = Amount of CH<sub>4</sub> generated from decomposable material x in year T, expressed in tonnes of CH<sub>4</sub>

DDOCm decomp<sub>x,T</sub> = DDOCm<sub>x</sub> decomposed in the landfill during year T, expressed in tonnes of CH<sub>4</sub> F = Fraction of CH<sub>4</sub>, by volume contained in the gas produced at the landfill. The default factor is 0.5. 16/12 = Molecular weight ratio of CH<sub>4</sub>/C

Table 29 presents the descriptions of the main parameters of the waste decomposition model, and Table 30, Table 31 and Table 32 present the parameters and factors to be used with Equation 23, Equation 24, Equation 25, Equation 26, Equation 27, and Equation 28 for CH<sub>4</sub> emissions from landfilling of municipal waste and other waste types. The values for k, DOC and DOCf are presented by waste type in Table 30. These same parameters have been grouped by sector according to time periods, based on characterization data, balances, or MELCC estimates and are presented in Table 30 or Table 31 and Table 32. The use of any values other than those presented in Tables 30 and 31 should be justified. The CH<sub>4</sub> recovered during year T (R<sub>T</sub>) must be determined and justified according to the biogas capture, destruction (e.g., flare) or upgrading system, and the landfill site.

Table 29. Pa	rameters of the First-order Decomposition Model for Landfill Waste
Parameter	Description
Degradable organic carbon (DOC)	DOC represents the amount of organic carbon in the waste material that is available for decomposition and is determined by the composition of the waste material deposited in the landfill. DOC is generally measured as a fraction of the wet weight of the waste.
Fraction of DOC that decomposes (DOC <sub>f</sub> )	DOC <sub>f</sub> is an estimate of the amount of DOC in waste materials that actually decomposes in landfills. The DOC <sub>f</sub> values by material are taken primarily from the 2019 Revision of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019). <sup>55</sup>
Methane correction factor (MCF)	The MCF accounts for the decomposition of waste materials under different management practices. It is used to account for the fact that unmanaged landfills produce less CH <sub>4</sub> from a given amount of material than managed landfills in an anaerobic environment (IPCC, 2006). For sanitary and engineered landfills in Quebec, the recommended value is 1.
Reaction constant (k)	k represents the rate at which CH <sub>4</sub> is generated in the first-order decomposition reaction after the waste material is deposited in the landfill. The value of k is influenced by moisture content, nutrient availability, pH, and temperature, among other factors. The 2006 IPCC Guidelines decay rate constants (k) for the boreal-temperate wet and dry climate zones are used (IPCC 2006). The "wet" and "dry" climates are defined by the ratio of mean annual precipitation to potential evapotranspiration: wet climates have a mean annual precipitation that is greater than the potential evapotranspiration.
Fraction of CH <sub>4</sub> in biogas (F)	F is the volume fraction of methane in the biogas produced by the decomposition of waste materials. The 2006 IPCC Guidelines (IPCC 2006) recommend a default value of 0.5.

<sup>&</sup>lt;sup>54</sup> Modified from Equation 3.6 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 3.

<sup>&</sup>lt;sup>55</sup> The values for materials F and G (Table 25) were adapted by the Direction de l'expertise en réduction des émissions de GES of the MELCC.

Oxidation	factor	OX represents the amount of CH <sub>4</sub> that is oxidized to CO <sub>2</sub> by methanotrophic microorganisms as it passes		
(OX)		through the landfill cover material. The default value of 0.1 from the 2006 IPCC Guidelines (IPCC,		
		2006) for managed landfills covered with a CH4-oxidizing material is recommended.		
Source: National Inventory Report 1990-2020: Greenhouse Gas Sources and Sinks in Canada. Part 2 - Section A3.6.1.2.1.				

Based on characterizations of types of waste materials landfilled, covering various periods, the MELCCFP has developed default values for the parameters DOC x DOC<sub>f</sub> and k according to sectors and periods. These parameters can be used for the purposes of calculating emissions from landfilling of waste materials.

Table 30. DOC, DOCf and k Parameters by Type of Waste						
	Types of waste	DOC	DOCf	k		
Α	Paper	0.4	0.5	0.06		
В	Garden waste	0.2	0.7	0.1		
С	Table scraps	0.15	0.7	0.185		
D	Layer	0.24	0.5	0.185		
Е	Textiles	0.24	0.5	0.06		
F	Other organic materials	0.4	0.5	0.1		
G	Building materials	0.22	0.1	0.03		
Н	Wood	0.43	0.1	0.03		
	Sludge	0.13	0.5	0.185		

\*Sludge is considered to be 29% dry.

Table 31. DOC x DOCf Parameters According to Sectors and Sludge				
Periods	Parameters: DOCxDOC <sub>f</sub>			
		Sectors		Input
	Residential	CRD	ICI	Sludge
1941–1969	0.1298	0.0311	0.1413	0.065
1970–1989	0.1234	0.0311	0.1413	0.065
1990–2006	0.1173	0.0311	0.1413	0.065
2007–2011	0.1105	0.0311	0.1413	0.065
2012–2015	0.1099	0.0306	0.0938	0.065
2016–2019	0.1034	0.0306	0.0938	0.065
2020 and after	0.0935	0.0316	0.0866	0.065

Table 32. Parameter k According to Sectors and Sludge				
Periods	Parameter: k			
		Sectors		Input
	Residential	CRD	ICI	Sludge
1941–1969	0.0661	0.0555	0.0659	0.185
1970–1989	0.0735	0.0555	0.0659	0.185
1990–2006	0.0806	0.0555	0.0659	0.185
2007–2011	0.0930	0.0555	0.0659	0.185
2012–2015	0.0988	0.0366	0.0814	0.185
2016–2019	0.0972	0.0366	0.0814	0.185
2020 and after	0.0878	0.0340	0.0688	0.185

### 1.25.3 Biogas Upgrading and Calculation of Associated GHG Reductions

For any landfill project subjected to an environmental authorization, the Regulation respecting the landfilling and incineration of residual materials (REIMR) requires, at a minimum, the installation of a system to capture the biogas generated and, if the landfill site receives 50,000 tonnes of residual materials or more per year or has a maximum capacity of more than 1.5 million m<sup>3</sup> of residual materials, it is also required that the captured biogas be sent to an upgrading (e.g., gas network) or destruction (e.g., flaring) facility. The MELCCFP encourages the use of biogas as a substitute for fossil fuels whenever possible. Where biogas upgrading is planned as an alternative to flaring, the GHG emission reductions from the project can be quantified. Biogas upgrading could reduce the project's fossil fuel bill or reduce GHG emissions from users outside the project. The calculation of GHG reductions can be done using the equations presented in <u>sections 1.9</u> and <u>1.10</u> on stationary and mobile combustion systems, depending on the type of biogas use.

## 1.26 GHG Emissions from Energy Use in Biogas Cleaning Operations

GHG emissions attributable to energy consumption in biogas cleaning operations should be calculated in sections 1.9 and 1.10 on stationary and mobile combustion systems.

## 1.27 CH<sub>4</sub> Emissions from Biogas Destruction

CH<sub>4</sub> emissions from this operation can be estimated from Equation 29, which considers the amount of CH<sub>4</sub> sent to the flare and the CH<sub>4</sub> destruction efficiency factor in the flare (DE).

 $E_{CH4Comb} = Q_{CH4Comb} \times (1 - DE)$ 

#### Equation 29: Methane emissions from biogas combustion

Where:

 $E_{CH4Comb}$  = Methane emissions attributable to biogas combustion, expressed in tonnes of CH<sub>4</sub> per year

Q<sub>CH4Comb</sub> = Total amount of CH<sub>4</sub> sent to the flare per year, expressed in tonnes of CH<sub>4</sub> per year

DE = Biogas destruction efficiency

Table 33 shows the DE factor associated with different biogas destruction devices.

Table 33. Biogas Destruction Efficiency			
System, Equipment or Process for Destruction or Upgrading of	Efficiency Factor		
biogas			
Visible flame flare	0.96		
Invisible flame flare	0.995		
Internal combustion engine	0.936		
Boiler	0.98		
Micro or large gas turbine	0.995		
Use of gas as CNG/LNG fuel	0.95		

Injection into a natural gas transmission and distribution system (Factor	0.98
takes into account system losses and distribution leakage.)	
Off-site gas use under a direct-use agreement	Factor according to the agreement
Courses DOATO Protocol 2 longfills Old destruction or processing Table 4	

Source: RCATS, Protocol 2, landfills – CH4 destruction or processing, Table 1.

## **1.28 Fugitive CH<sub>4</sub> Emissions from Biomethanization of Organic Waste**

Biomethanization is a biological process (anaerobic fermentation) that allows the recovery of organic materials by producing biogas (mainly methane), a renewable energy source, and a digestate, which can be used as fertilizer. Biomethanization reduces the quantity of organic materials destined for disposal, thereby helping to achieve the environmental objectives set out in the Quebec Residual Materials Management Policy and reducing GHG emissions. The MELCC is responsible for the implementation of Quebec's biomethanization and composting program. It is mainly the very large cities that choose this method of managing organic materials, given the infrastructure required.

Although biomethanization is a GHG emissions reduction measure, some fugitive CH<sub>4</sub> emissions may be generated during the process. According to Equation 30, fugitive CH<sub>4</sub> emissions from the biomethanization process can be calculated from the amount of methane produced annually and the leakage rate from the process. For the CH<sub>4</sub> leakage rate from digesters, the Climate Action Reserve proposes a value of 0.02 in its "Organic Waste Digestion" protocol<sup>56</sup>.

 $E_{CH4BIOMET} = Q_{CH4BIOMET} \times T_{FCH4}$ 

#### Equation 30: Fugitive Methane Emissions from Biogas Processing

Where:

 $E_{CH4BIOMET}$  = GHG emissions attributable to the organic waste biomethanization process, in tonnes of CH<sub>4</sub> per year

QCH4BIOMET = Amount of methane produced, in tonnes of CH4 per year

 $T_{FCH4}$  = Methane leakage rate from the biomethanization process

## **1.29 GHG Emissions from Biogas Compression and Liquefaction**

For GHG emissions from methane compression and liquefaction, it is suggested to refer to the <u>RMRCECA</u> <u>Protocol QC.29</u> on emissions from processes and equipment used to transport and distribute natural gas.

## **1.30 CH<sub>4</sub> and N<sub>2</sub>O Emissions from Organic Waste Composting**

Composting is a measure used to reduce organic waste and GHG emissions. Small and medium-sized municipalities are the most likely to choose this method of organic waste management. Composting is a biological treatment process (aerobic fermentation, i.e., in the presence of oxygen) of organic materials. The organic materials are mixed with a structuring material that promotes aeration (e.g. wood chips) and placed in windrows, piles, or reactors. Compost is obtained after fermentation and maturation. Composting generates mostly CO<sub>2</sub> and small amounts of CH<sub>4</sub> and N<sub>2</sub>O.

<sup>&</sup>lt;sup>56</sup> Climate Action Reserve (Reserve), Organic Waste Digestion (OWD) Project Protocol Version 2.1, table B6.

However, since the CO<sub>2</sub> emissions released during composting result from the decomposition of organic materials from biomass sources, they are considered biogenic, and these emissions are not included in the Quebec GHG inventory. Therefore, estimates of GHG emissions from composting include only CH<sub>4</sub> and N<sub>2</sub>O emissions.

GHG emissions from composting can be quantified using Equation 31 and Equation 32, and the factors presented in Table 34.

Equation 31: Methane Emissions from Waste Composting

Where:

 $E_{CH4} = EF_{CH4} \times Qt_{OWM} \times 0.001$ 

*E*<sub>CH4</sub> = Annual CH<sub>4</sub> emissions from composting treatment, expressed in tonnes of CH<sub>4</sub> per year

 $EF_{CH4} = CH_4$  emission factor associated with composting treatment, expressed in kilograms of CH<sub>4</sub> per tonne of organic waste materials (OWM)

Qtowm = Quantity of OWM processed by composting, expressed in tonnes

0.001 = Conversion factor from kilograms to metric tonnes.

#### Equation 32: N<sub>2</sub>O Emissions from Waste Composting

$$E_{N2O} = EF_{N2O} \times Qt_{OWM} \times 0.001$$

Where:

 $E_{N2O}$  = Annual N<sub>2</sub>O emissions from composting treatment, in tonnes of N<sub>2</sub>O per year

 $EF_{N2O} = N_2O$  emission factor associated with composting treatment, in kilograms of N<sub>2</sub>O per tonne of OWM

*Qt*<sub>OWM</sub> = Amount of OWM processed by composting, in tonnes

0.001 = Conversion factor from kilograms to metric tonnes.

Table 34 presents CH<sub>4</sub> and N<sub>2</sub>O emission factors associated with waste composting.

Table 34. CH <sub>4</sub> and N <sub>2</sub> O Emission Factors Associated with OWM Composting					
Type of material	EFcH4	EF <sub>N2O</sub>	Reference		
	(kg CH4 /t оwм)	(kg N <sub>2</sub> O /t оwм)			
Yard waste	1.72	0.25	NIR 1990–		
Municipal solid waste	1.51	0.18	2022, Part II,		
Biosolids or manure	3.54	0.18	Table A6.7-4		
Mixture of the above co-composted wastes	1.09	0.11			

## 1.31 GHG Emissions from Waste Incineration or Thermal Treatment of Hazardous Materials or Contaminated Soil

Waste incineration or thermal treatment of hazardous materials or contaminated soils can be sources of  $CO_2$ ,  $CH_4$ , and  $N_2O$  emissions. The following sections present the equations for calculating GHG emissions from these activities.

#### 1.31.1 Fossil-based CO<sub>2</sub> Emissions from Municipal Waste Incineration (Other than Sludge)

The incineration of municipal waste generates CO<sub>2</sub> emissions from the fossil carbon it contains. For the nonbiomass (i.e. non-biogenic) portion of municipal waste, emissions can be quantified using Equation 33<sup>57</sup>. Sludge incineration is discussed in the next section.

Equation 33: Non-biogenic CO<sub>2</sub> Emissions from Municipal Waste Incineration, Other than Sludge

 $E_{MW} CO_{2f} = MW \times (1 - PAB) \times EF_{MW} \times HHV_{MW} \times OF \times 0.001$ 

Where:

 $E_{MW}$  CO<sub>2f</sub> = Annual CO<sub>2</sub> emissions from municipal waste incineration in tonnes of CO<sub>2</sub> equivalent per year

MW = Total mass of municipal waste (wet weight) incinerated, expressed in tonnes per year

PAB = Biomass fraction of municipal waste

EF<sub>MW</sub> = CO<sub>2</sub> emission factor associated with municipal waste (85.6 kg/GJ)

 $HHV_{MW}$  = Higher heating value of municipal waste, default value = 11.57 GJ/tonne of municipal waste

OF = Oxidation factor, default value = 1 (100%)

0.001 = Conversion factor from kilograms to metric tonnes.

## 1.31.2 Fossil-based CO<sub>2</sub> Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous waste, Biomedical Waste, and Sewage Sludge

Incineration and thermal treatment of waste materials generate non-biogenic CO<sub>2</sub> emissions from the fossil carbon contained in these materials. Equation 34 is used to quantify these emissions<sup>58</sup>.

<sup>&</sup>lt;sup>57</sup> Adapted from RMRCECA Equation 1-1.

<sup>58 2006</sup> IPCC Guidelines for National Greenhouse Gas Inventories.

Equation 34: Non-biogenic CO<sub>2</sub> Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge

$$E_W CO_2 = \sum_i (W_i \times dm_i \times FC_i \times FFC_i \times OF_i) \times \frac{44}{12}$$

Where:

 $E_W CO_2$  = Annual non-biodegradable CO<sub>2</sub> emissions from the incineration or thermal treatment of nonmunicipal waste, in tonnes of CO<sub>2</sub> equivalent per year

W<sub>i</sub> = Total amount of waste type i (wet weight) incinerated, in tonnes per year

*dm*<sup>*i*</sup> = *Dry matter content of waste* (*wet weight*) *incinerated*, (*fraction*)

*FC<sub>i</sub>* = *Fraction of carbon in dry matter (total carbon content)* 

*FFC*<sup>*i*</sup> = *Fraction of fossil carbon in total carbon, (fraction)* 

 $OF_i$  = Oxidation factor, default value = 1 (100%)

44/12 = Conversion factor of C to CO<sub>2</sub>

*i* = Type of waste incinerated or thermally treated: municipal, industrial or hazardous waste, biomedical waste, or sewage sludge

Table 35 presents the carbon factor (CF) and fossil carbon factor (FCF) in waste materials to be used in Equation 34. These factors are taken from best practice guides, the 2006 IPCC<sup>59</sup> Guidelines, and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 35. Default Factors for the Calculation of CO <sub>2</sub> Emissions				
Types of Non-municipal Waste Incinerated or Treated	FC: Fraction of Carbon in Dry Matter (%)	FCF: Fraction of Fossil Carbon in Total Carbon (%)	References	
Industrial	50	90	1	
Hazardous	50	90	2	
Biomedical waste	60	40	1	
Sludge:				
- Municipal	31	0	3	
- Food industry	44	0	3	
- Paper industry (process sludge)	28	0	3	
- Paper industry (sewage sludge)	31	0	3	

1. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 5, Table 5.2.

2. 2006 IPCC Guidelines. Volume 5: Waste. Chapter 5. Table 5.6.

3. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 2, Table 2.4A.

## 1.31.3 CH<sub>4</sub> Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge

CH<sub>4</sub> emissions from incineration or thermal treatment are mainly the result of incomplete combustion of waste materials. They are influenced by the following parameters: the technology used, the operating mode, the temperature, the residence time, and the air index. Equation 35 quantifies these emissions<sup>60</sup>.

<sup>&</sup>lt;sup>59</sup> IPCC (2000). IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

<sup>&</sup>lt;sup>60</sup> 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Equation 35: CH<sub>4</sub> Emissions from Incineration or Thermal Treatment of Waste

$$E_W CH_4 = \sum_i (W_i \times EF_i CH_4) \times 0.001$$

Where:

*E*<sub>*w*</sub> CH<sub>4</sub> = Annual CH<sub>4</sub> emissions, expressed in tonnes of CH<sub>4</sub> per year

 $W_i$  = Amount of waste material of type i incinerated or thermally treated annually, expressed in tonnes per year

 $EF_i CH_4 = CH_4$  emission factor associated with waste type *i*, expressed in kilograms of CH<sub>4</sub> per tonne of waste, Table 35

10<sup>-6</sup>= Conversion factor from grams to tonnes

*i* = Category or type of waste incinerated or thermally treated, specified as follows:

*MW:* municipal waste; *IW:* industrial waste; *HW:* hazardous waste; *BW:* biomedical waste; and *SS:* sewage sludge.

Table 36 shows CH<sub>4</sub> and N<sub>2</sub>O emission factors for the incineration of different types of waste depending on the type of facility. These factors can be used in Equation 35 and Equation 36.

Table 36. Default CH <sub>4</sub> and N <sub>2</sub> O Emission Factors for Incineration Facilities					
Type of Waste	Type of Feed	Type of Incinerator	EF CH <sub>4</sub>	EF N <sub>2</sub> O	
			(g/t)	(g/t)	
Municipal solid waste	Continuous	Mechanical furnace	0.2	50	
Municipal solid waste	Continuous	Fluidized bed	0	50	
Municipal solid waste	Semi-continuous	Mechanical furnace	6	50	
Municipal solid waste	Semi-continuous	Fluidized bed	188	50	
Municipal solid waste	Batch	Mechanical furnace	60	60	
Municipal solid waste	Batch	Fluidized bed	237	60	
Hazardous waste	Continuous	Mechanical furnace	169.49	3 163.84	
Hazardous waste	Batch	Mechanical furnace	169.49	3 163.84	
Sewage sludge	Continuous	Fluidized bed	9.70	990	
Sewage sludge	Continuous	Mechanical furnace	9.70	990	
Medical waste	Continuous	Mechanical furnace	0.20	50	
Medical waste	Batch	Mechanical furnace	60	60	
Medical waste	Semi-continuous	Mechanical furnace	0.20	50	
Other sludge	Continuous	Mechanical furnace	0.20	450	
Other sludge	Batch	Mechanical furnace	60	450	
Fossil-based liquid waste	Continuous	Mechanical furnace	0.20	100	

Table 36. Default CH <sub>4</sub> and N <sub>2</sub> O Emission Factors for Incineration Facilities					
Type of Waste	Type of Feed	Type of Incinerator	EF CH₄ (g/t)	EF N₂O (g/t)	
Fossil-based liquid waste	Batch	Mechanical furnace	60	100	
Industrial waste	Continuous	Mechanical furnace	0.20	50	
Industrial waste	Continuous	Fluidized bed	0	50	
Industrial waste	Semi-continuous	Mechanical furnace	6	50	
Industrial waste	Semi-continuous	Fluidized bed	188	50	
Industrial waste	Batch	Mechanical furnace	60	60	
Industrial waste	Batch	Fluidized bed	237	60	

Source: National Inventory Report (NIR) 1990-2022. Part II. Table A3.6-12.

# 1.31.4 N<sub>2</sub>O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge Calculated from Emission Factors

Nitrous oxide emissions are influenced by the temperature of the combustion process, the air pollution control device, the type and nitrogen content of the waste, and the air index. Equation 36 is used to quantify these emissions<sup>61</sup>.

## Equation 36: N<sub>2</sub>O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge Calculated from Emission Factors

$$E_W N_2 O = \sum_i (W_i \times EF_i N_2 O) \times 0.001$$

Where:

 $E_W N_2 O = N_2 O$  emissions, in tonnes of  $N_2 O$  per year

*W<sub>i</sub>* = Amount of waste type *i* incinerated or thermally treated, in tonnes per year

 $EF_i N_2O = N_2O$  emission factor associated with waste type i, in kilograms of  $N_2O$  per tonne of waste, obtained from Table 35

0.001 = Conversion factor from kilograms to tonnes

*i* = Category or type of waste incinerated or thermally treated, specified as follows:

*MW:* municipal waste; *IW:* industrial waste; *HW:* hazardous waste; *BW:* biomedical waste; and *SS:* sewage sludge.

## 1.31.5 N<sub>2</sub>O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge, based on Flue Gas concentration data

Where flue gas concentration data for N<sub>2</sub>O is available, N<sub>2</sub>O emissions from waste incineration can be calculated from Equation 37<sup>62</sup>.

<sup>61 2019</sup> Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

<sup>&</sup>lt;sup>62</sup> 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Equation 37: N<sub>2</sub>O Emissions from Incineration or Thermal Treatment of Municipal, Industrial and Hazardous Waste, Biomedical Waste, and Sewage Sludge, Based on Flue Gas Concentration Data

$$E_W N_2 O = \sum_i (W_i \times CE_i \times VFG_i) \times 10^{-9}$$

Where:

 $E_W N_2 O = Annual N_2 O$  emissions, in tonnes of  $N_2 O$  per year

*W<sub>i</sub>* = Amount of waste type *i* incinerated or thermally treated, in tonnes per year

 $CE_i$  = Concentration of N<sub>2</sub>O emissions in the flue gas from the incineration of waste type *i*, in mg N<sub>2</sub>O/m<sup>3</sup>

VFG<sub>i</sub> = Volume of flue gas per quantity of waste type i incinerated, in m<sup>3</sup>/tonne

10-9= Conversion factor from milligrams to tonnes

*i* = Category or type of waste incinerated or thermally treated, specified as follows:

*MW:* municipal waste; *IW:* industrial waste; *HW:* hazardous waste; *BW:* biomedical waste; and *SS:* sewage sludge.

#### 1.31.6 Energy Recovery and Associated GHG Emissions Reduction

If waste energy is recovered to replace fossil fuels, this contributes to reducing GHG emissions. In Quebec, there are several examples of energy being sold to nearby industries (e.g. steam network). If a recovery of the residual energy generated is planned, it is suggested to quantify the related GHG emission reductions. To do so, the equation provided in <u>Section 1.9</u> on stationary combustion systems can be used.

### **1.32 Emissions from Wastewater Treatment and Discharge**

These include CH<sub>4</sub> and N<sub>2</sub>O emissions from municipal and industrial wastewater treatment, as well as CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated wastewater discharge.

#### 1.32.1 CH<sub>4</sub> emissions from wastewater treatment or discharge

The methodology for estimating CH<sub>4</sub> emissions from wastewater treatment or discharge presented in this guide follows the recommendations of the IPCC guidelines. CH<sub>4</sub> emissions are estimated based on the organic matter load in the wastewater, the maximum methane production capacity (Bo), and the methane correction factor (MCF), which is a function of the type of wastewater treatment performed. Equation 38 calculates methane emissions from wastewater treatment, in tonnes of CH<sub>4</sub> per year.

Equation 38: CH<sub>4</sub> emissions from wastewater treatment or discharge

 $CH_4 = (EF_{CH4(treat)} \times Lo_{Org} \times Eff + EF_{CH4(dis)} \times Lo_{Org} \times (1 - Eff)) \times 0.001$ 

Where:

 $CH_4 = CH_4$  emissions attributable to wastewater treatment and discharge, expressed in tonnes of  $CH_4$  per year

 $EF_{CH4(treat)}$  = Methane emission factor associated with wastewater treatment, expressed in kg CH<sub>4</sub>/kg BOD5
Loorg = Total annual organic load from the wastewater treatment plant, expressed in kilograms of BOD<sub>5</sub> per year

 $EF_{CH4(dis)}$  = Methane emission factor associated with direct wastewater discharge, expressed in kg CH<sub>4</sub>/kg BOD5. Since the types of receiving water bodies may be unknown, this guide uses the Tier 1 emission factor from the 1990-2019 NIR, which is 0.0396 kg CH<sub>4</sub>/kg BOD5.

*Eff* = Wastewater treatment efficiency. Fraction of wastewater organic load removed during treatment. 0.001 = Conversion factor from kilograms to tonnes

Organic load is determined from the organic load rate per capita per day and an industrial and commercial input correction factor of 1.25<sup>63</sup>.

#### Equation 39: Calculation of Annual Organic Load

$$Lo_{Org} = Pop \times BOD_{Cap.day} \times 1.25 \times 365$$

Where:

Lo<sub>Org</sub> = Total annual organic load from the wastewater treatment plant, expressed in kilograms of BOD<sub>5</sub> per year

Pop = Population that is connected to the wastewater treatment system

BODcap.day = Organic load per capita per day = 0.06 kg BOD<sub>5</sub>/person/day

1.25 = Correction factor for industrial and commercial inputs

365 = Days/year correction factor

Table 37 presents the methane emission factors associated with different types of wastewater treatment.

Table 37. Methane Emission Factors Associated with Different Types of Wastewater Treatment			
Type of Treatment	EFCH4(treat) (kg CH4/kg BOD)	Eff	
No treatment	0	0	
Primary treatment	0.0108	0.4	
Aerobic lagoon	0	0.85	
Anaerobic lagoon	0.288	0.85	
Facultative lagoon	0.072	0.85	
Other / "unspecified" type of lagoon	0.072	0.85	
Anaerobic secondary treatment	0.288	0.85	
Secondary activated sludge treatment	0.0108	0.95	
Bacterial bed	0.0108	0.85	
Bacterial bed (high load)	0.0108	0.85	
Biological discs	0.0108	0.85	
Sequential biological reactors (SBR)	0.018	0.9	
Secondary treatment by biofiltration	0.0108	0.95	
Secondary treatment with biological nutrient removal	0.0108	0.98	
Septic tank	0.18	1	
Septic tank with ocean discharge	0.18	0.625	
Wetlands	0.0612	0.975	
Other / unknown	0.072	0.85	

Source: Adapted from the National Inventory Report (RIN) 1990-2022. Part II. Table A3.6-14.

<sup>63 2019</sup> Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste. Chapter 6. Wastewater treatment and discharge.

#### 1.32.2 N<sub>2</sub>O Emissions from Wastewater Treatment or Discharge

N<sub>2</sub>O emissions can originate directly from wastewater treatment facilities or be generated indirectly from wastewater after the effluent is discharged to streams, lakes, or the sea. Direct emissions, resulting from nitrification and denitrification, at wastewater treatment facilities can be considered minor sources and therefore negligible, except for more sophisticated facilities with the capacity to nitrify and denitrify effluent (IPCC, 2006).

Equation 40 presents N<sub>2</sub>O emissions from wastewater treatment, expressed in tonnes of N<sub>2</sub>O per year.

Equation 40: N<sub>2</sub>O Emissions from Wastewater Treatment or Discharge

$$E_{N20} = EF_{N20} \times N \times \frac{44}{28} \times 0.001$$

Where:

 $EN_2O = N_2O$  emissions from wastewater treatment, expressed in tonnes of N<sub>2</sub>O per year  $EFN_2O = N_2O$  emission factor from wastewater, use Table 38 N = Amount of nitrogen in wastewater, in kilograms of N per year 44/28 = Stoichiometric factor used to convert molecular nitrogen to N<sub>2</sub>O 0.001 = Conversion factor from kilograms to tonnes

Therefore, according to Equation 40, N<sub>2</sub>O emissions are directly proportional to the amount of nitrogen in the wastewater and the N<sub>2</sub>O emission factor. The latter is characteristic of each type of treatment or discharge and can be estimated from Table 38.

Industrial Wastewater Treatment			
Type of Treatment or Disposal Route for Wastewater	Observations	EF <sub>N20</sub> (kg N <sub>2</sub> O/kg N)	
Untreated wastewater			
Discharge to freshwater, estuaries, and the sea (Tier 1)	Based on limited field data and specific assumptions regarding the occurrence of nitrification and denitrification in rivers and estuaries.	0.005	
Discharge to eutrophic or hypoxic environments (Tier 3, if required)	Higher emissions are associated with hypoxic or nutrient- enriched waters, such as those in eutrophic lakes, estuaries, and rivers, or where stagnant conditions prevail.	0.019	
Treated wastewater			
Centralized aerobic treatment plants	N <sub>2</sub> O is variable and can be significant.	0.016	
Anaerobic reactor	N <sub>2</sub> O is not significant.	0	
Anaerobic lagoon	N <sub>2</sub> O is not significant.	0	
Engineered wetland	Refer to the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC 2014).		
Septic tank	N <sub>2</sub> O is not significant.	0	
Septic tank and disposal field	N <sub>2</sub> O is emitted by the disposal field.	0.0045	
Latrine	N <sub>2</sub> O is not significant.	0	
Anaerobic sludge digester	N <sub>2</sub> O is not significant.	0	

Table 29 N.O.Emission Easters Associated with Different Types of Desidential

Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste. Chapter 6. Wastewater treatment and discharge. Table 6.3.

The total amount of nitrogen to be treated can be estimated based on the population served by the treatment plant (municipal wastewater) or the nitrogen load to be treated at the industrial wastewater treatment plant (industrial wastewater). Equation 41 and Equation 42 are used to estimate the total amount of nitrogen to be treated for domestic wastewater and industrial wastewater, respectively.

#### Equation 41: Total Nitrogen in Municipal Wastewater

 $N = Proteins \times Population \times F_{NPR} \times F_{household} \times F_{NC}$ 

Where:

N = Total nitrogen in municipal wastewater, in kilograms of N per year

Proteins = Annual protein consumption per person = 69.85 kilograms per person per year<sup>64</sup>

Population = Population served by wastewater treatment facilities

 $F_{NPR}$  = Fraction of nitrogen in protein = 0.16 kilogram of N per kilogram of protein<sup>65</sup>

*F*<sub>household</sub> = Additional fraction of nitrogen from household products = 1.17<sup>66</sup>

 $F_{NC}$  = Fraction of protein not consumed = 1.13<sup>67</sup>

<sup>&</sup>lt;sup>64</sup> NIR 1990-2022. Part II. Table A3.6-18.

<sup>65 2019</sup> Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5, Chapter 6, page 6.38.

<sup>66 2019</sup> Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5, Chapter 6, Table 6.10A.

<sup>67 2019</sup> Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5, Chapter 6, Table 6.10A.

For industrial wastewater treatment plants, Equation 44 estimates the total amount of nitrogen treated at the treatment plant by multiplying the annual flow of treated wastewater by the total influent nitrogen concentration.

Equation 42: Total Amount of Nitrogen Present in Industrial Wastewater

 $N = D\acute{e}bit_{Annuel} \times CNitrogen_{Inf}$ 

Where:

*N* = Total nitrogen in municipal wastewater, in kilograms of *N* per year

Annualflow = Annual flow of treated wastewater at the treatment plant, in cubic metres per year

 $CNitrogen_{Inf}$  = Total concentration of nitrogen in the treated influent at the treatment plant, in kilograms of N per cubic metre

In the event that the type of treatment and its rate of nitrogen removal is known, Equation 43 can be used to determine the total amount of nitrogen sent to the effluent.

#### Equation 43: Total Amount of Nitrogen Sent to Effluent

Where:

N<sub>EFF</sub> = Total amount of nitrogen sent to the effluent, expressed in kilograms of N per year

N = Amount of nitrogen present in industrial wastewater, expressed in kilograms of N per year

 $N_{EFF} = N \times (1 - N_{REM})$ 

*N*<sub>REM</sub> = Fraction of nitrogen removed during wastewater treatment, obtained from Table 39

# Table 39. Fraction of Nitrogen Removed During Wastewater Treatment (NREM)

Type of treatment	Default value for nitrogen removal	Range of values for nitrogen removal
No treatment	0	0
Primary treatment (mechanical)	0.10	0.05 to 0.20
Secondary treatment (biological)	0.40	0.35 to 0.55
Tertiary treatment (advanced biological)	0.80	0.45 to 0.85
Septic tank	0.15	0.10 to 0.25
Septic tank and disposal field	0.68	0.62 to 0.73
Latrine	0.12	0.07 to 0.21

Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5, Chapter 6, Tableau 6.10c.

# **1.33 Hydrocarbon Exploration and Development**

## 1.33.1 Context in Quebec

The adoption, on April 12, 2022, of <u>Bill 21, an Act mainly to end petroleum exploration and production and</u> <u>the public financing of those activities</u>, puts an end to hydrocarbon exploration and development activities as well as production of brine in Quebec. Historically, more than 900 oil and gas wells have been drilled in Quebec since 1860, but the industry has not developed much in the province. Three hydrocarbon exploration and development projects in Quebec have received media attention over the past decade. These projects include the potential development of shale gas in the St. Lawrence Valley, the potential development of shale gas and oil in Anticosti and Quebec, and the development of hydrocarbons from the Old Harry formation in the Gulf of St. Lawrence near the Magdalen Islands. These projects served as references for the development of the GHG emissions quantification methodologies in this guide. Despite the adoption of Bill 21, this section has been retained because some of the methodologies could be applicable to other sectors, such as the closure of orphan hydrocarbon wells in Quebec.<sup>68</sup>

For the quantification of GHG emissions, this section is based on the numerous reports and studies produced in the context of various strategic environmental assessments (SEAs), on the regulations in force in Quebec (RMRCECA), in the United States (United States Environmental Protection Agency [US EPA]), and in Canada, as well as on the MELCCFP's Interim Guidelines for Oil and Gas Exploration<sup>69</sup>. In addition, some methodologies from the American Petroleum Institute (API) are used as references. Finally, among the references concerning the impacts of hydrocarbon exploration and development on GHG emissions applicable to the Quebec context, we can cite the studies of the International Reference Center for Life Cycle Assessment and Sustainable Transition (CIRAIG)<sup>70</sup> (2013), WSP<sup>71</sup> (2015), and the MELCCFP<sup>72</sup> (2013).

As the state of knowledge on this sector is not very advanced in Quebec, the precautionary principle must be applied for this type of project, and a specific process must also be applied to determine the sources of GHG emissions. This section as well as Appendix B present applicable methodologies to assess GHG emissions from hydrocarbon exploration and development activities.

#### 1.33.2 Description of the sequence of operations

Appendix B presents the general sequence of operations for a typical shale oil exploration and development project (Ref: WSP, 2015). Due to the wide variability of activities related to hydrocarbon exploration and development (e.g., drilling with hydraulic fracturing or "conventional" drilling), some elements may not be identified in the guide or, alternatively, may cover a broader spectrum. In any case, it is important to identify all phases, activities, and equipment that have GHG emissions impacts as part of the project.

The following is a summary of the main phases and activities to be considered in the quantification of GHG emissions (non-exhaustive list).

<sup>&</sup>lt;sup>68</sup> Ministère de l'Énergie et des Ressources naturelles, March 2021. <u>Rapport sur l'état des puits d'hydrocarbures inactifs au Québec</u> (Status report on inactive hydrocarbon wells in Quebec).

<sup>69</sup> MELCC, 2014 : http://www.environnement.gouv.qc.ca/industriel/hydrocarbures/lignes-directrices.pdf.

<sup>&</sup>lt;sup>70</sup> CIRAIG, 2013. Rapport synthèse des résultats du CIRAIG sur l'impact des émissions de GES de la filière du gaz de schiste au Québec (Summary report on the CIRAIG's findings about the impact of GHG emissions from Quebec's shale gas industry). http://www.bape.gouv.qc.ca/sections/mandats/gaz\_de\_schisteenjeux/documents/PR3.6.24.pdf.

<sup>&</sup>lt;sup>71</sup> WSP, October 2015. Élaboration d'un projet type concernant les activités d'exploration et d'exploitation du pétrole et du gaz à Anticosti (Sample project preparation regarding oil and gas exploration and development activities in Anticosti). Study AENV17, https://mern.gouv.qc.ca/energie/filierehydrocarbures/etudes/AENV17.pdf.

<sup>&</sup>lt;sup>72</sup> MELCC, December 2013. Rapport synthèse des résultats du CIRAIG sur l'impact des émissions de GES de la filière du gaz de schiste au Québec (Summary report on the CIRAIG's findings about the impact of GHG emissions from Quebec's shale gas industry). http://www.bape.gouv.qc.ca/sections/mandats/gaz\_de\_schiste-enjeux/documents/PR3.6.24.pdf.

#### A. RAW MATERIAL SUPPLY (UPSTREAM)

- B. PRELIMINARY WORK
  - Geophysical and other surveys, sampling and testing
  - Site preparation

#### C. EXPLORATION

- Drilling of boreholes and wells
- Hydraulic fracturing
- Production testing

#### D. PILOT PROJECT/DEVELOPMENT

- Well drilling
- Hydraulic fracturing
- Production testing

#### E. HYDROCARBON PRODUCTION

- Oil-water separation
- Pumping of hydrocarbons
- Gas compression
- Gas dehydration
- Gas decarbonation
- Natural gas transfer
- Natural gas liquefaction
- LPG storage
- Condensate storage
- CO<sub>2</sub> sequestration

#### F. TRANSPORTATION AND DISTRIBUTION

- Transport by pipeline, gas pipeline, ship, train, or truck
- G. FINAL CLOSURE
  - Decommissioning of surface equipment
  - Closing of wells
  - Site reclamation

#### H. WASTE AND TAILINGS MANAGEMENT

- Sludge and spoil
- Wastewater
- Air emissions
- Accidental releases
- Equipment management

## I. POST-CLOSURE MONITORING

• GHG emissions monitoring program, including fugitive emissions

## 1.33.3 Equation-based GHG Emissions Calculations

GHG emission sources should be identified in a clear and detailed manner, and GHG emissions should be quantified for each phase and activity. This allows for a clear identification of the most GHG-emitting activities and potentially gives an overview of possible mitigation measures. In particular, activities related to hydrocarbon extraction and well production testing (Phases D and E) should be detailed, given their associated emission potential.

Table 40 provides examples of emission sources that must be considered, at a minimum. The formulas and methodologies proposed are for illustrative purposes. Other methodologies or references could be used depending on the specific needs of the project. If so, they must be well documented and based on reliable and verifiable sources.

	Table 40. GHG Emission Sources and References for Quantification			
No.	Sources	References - Quantification		
	Sources - Combustion			
1	Internal combustion engine, diesel or otherwise, for transporting materials, equipment or process-specific inputs, including air, sea, and land transport by rail or truck	RMRCECA Protocol QC.27		
2	Internal combustion engine, diesel or otherwise, for mobile equipment (off-road machinery, pumping trucks, mixing equipment, etc.)	RMRCECA Protocol QC.27		
3	Internal combustion engine, diesel or otherwise, for passenger transportation if applicable, including air, sea, and land (rail or truck)	RMRCECA Protocol QC.27 (methodology applicable even if transportation of people is initially excluded) and API Guide Section 4.8		
4	Internal combustion engine, diesel or otherwise (including natural gas or ethane) for generator sets (local power generation) or other stationary equipment such as compressors and pumps	RMRCECA Protocols QC.1 and QC.16 (generators)		
5	Oil, diesel, natural gas, ethane, or other fuel-fired boilers and heaters (heat production - e.g., for frac water or gas heating or glycol regeneration)	RMRCECA protocol QC.1		
6	Flare or other gas destruction equipment (burn pit)	RMRCECA Protocol QC.33.3.13 or API Guide Section 4.6 for flares and RMRCECA Protocol QC.1 for all other equipment		
7	Incinerator, thermal or catalytic oxidizer	RMRCECA Protocol QC.1 (incinerator) and API Guide Section 4.7		
8	Oil, ethane, natural gas, diesel or other fossil fuel-fired power plant for local electricity generation (including cogeneration)	RMRCECA Protocol QC.16 and API Guide Section 7.2		
	Sources - Processes			
9	Process micro-leaks - flanges and fittings (piping or equipment), manual or control valves, instruments, etc.	RMRCECA Protocol QC.33.3.16/17 and API Guide Section 6.1.3		
10	Safety valve openings (one-time events)	Sections 5.7 and B7.3 of the API Guide		
11	Compressor vents (centrifugal or reciprocating)	RMRCECA Protocols QC.33.3.14/15		

	Table 40. GHG Emission Sources and References for Quantification			
No.	Sources	References - Quantification		
12	Well gas or natural gas pneumatic actuator vents	RMRCECA QC.33.3.1/2 protocols and API		
12		Guide Section 5.6.1		
13	Well gas or natural gas air pump vents	RMRCECA Protocol QC.33.3.1 and API Guide		
10		Section 5.6.2		
14	End product or transfer tank vents (oil, condensate, etc.)	RMRCECA Protocol QC.33.3.9 and API Guide		
45	Fuel teals use to (diagonal an others)	Section 5.4.1/2/4		
15	Fuel tank vents (diesel or other)	Chapter 7 of the US EPA AP42 Guide		
10	Provback water storage tank vents	API Guide Section 5.4.3		
10	Emissions from water treatment or flowback tanks	API Guide Section 5.0.5		
10	Emissions from water treatment of howback tanks	APT Guide Section 0.2.1		
19		RMRCECA Protocol QC.55.5.5 and API Guide		
	Glycol regenerator vents (dehydrators)	RMRCECA Protocol OC 33 3 4 and API Guide		
20		Section 5 1/3/4		
	Gas separators	See references associated with the following		
		sources, as applicable: process micro-leaks -		
21		flanges and fittings, fugitive emissions from		
		completion and flaring		
00	Equipment blowdowns for maintenance or other purposes	RMRCECA Protocol QC.33.3.7 and API Guide		
22		Section 5.7.2		
	Sources – Other Losses			
23	Fugitive emissions during completion (including fracturing),	RMRCECA Protocols QC.33.3.6 and QC.33.4.6		
25	workover, or production testing (CO <sub>2</sub> or methane)	and API Guide Section 5.7.2		
24	Venting of gas from wells into the atmosphere (no flare or	RMRCECA Protocol QC.33.3.11 and API Guide		
27	not operating) during production testing	Section 5.7.2		
25	Fugitive emissions from wellhead vents (CO <sub>2</sub> or methane)	RMRCECA Protocols QC.33.3.5 and		
		QC33.3.11		
26	Fugitive emissions with flowback water during fracturing	See references for the following sources:		
		flowback tank and gas separator		
27	Losses during filling (truck, train or ship) and ballasting	Sections 5.5.1 and 5.5.2 of the API Guide		
	operations			
00	Sources - Other			
28	Emissions from the use of explosives	Section 3.7 of this guide		
29	Deforestation during construction	Sections 3.10.1 and 3.10.2 of this guide		
30	Off-site electricity generation (indirect)	Section 3.3 of this guide		
31	(indirect)	Sections 7.1.5 and 7.1.6 of the API Guide		
<u> </u>	Emissions from construction activities (buildings, related	See the references associated with the		
32	facilities oil and gas ninelines tanks etc.)	following source: mobile or stationary		
02		combustion equipment		
	Fugitive emissions due to the use of refrigeration or air	Section 3.9 of this guide and Section 6.4.1 of		
33	conditioning equipment	the API Guide		
34	Any other source associated with the project	To be specified in the calculation		

#### 1.33.4 Calculation of GHG emissions based on Emission Rates

If the project includes an air dispersion study for contaminants, the emission rate method could be used for the project-specific greenhouse gases from each source. Studies conducted as part of strategic environmental assessments can be referenced for methodological examples (WSP, 2015<sup>73</sup> and SNC-Lavalin, 2013<sup>74</sup>). Details of the methodology used must be provided.

## 1.33.5 Presentation of results

At a minimum, the following elements should be included in the description of the GHG assessment methodology:

- The detailed sequence of operations
- The list of equipment required to carry out the activities and their operating parameters
- The GHG emission sources, including fugitive emissions
- The emission factors and models
- The duration of the activities and use of the equipment
- The physical characteristics of the site that impact GHGs (e.g., number of well pads and pad size);
- The properties and characteristics of the hydrocarbons considered in the calculations (e.g., heating value, gas composition, liquid hydrocarbon composition, CO<sub>2</sub> concentration in the gas or liquid hydrocarbon, sulfur composition, and production rate);
- The references and data sources used for quantification (e.g., RMRCECA, US EPA, API).

For the presentation of results, a table of GHG emissions must be provided for each phase of the project. Emissions must be broken down by emitting activities or equipment, by type of gas, and in CO<sub>2</sub> equivalent. Appendix B provides sample tables of results that should be minimally included in the quantification report.

# 1.34 Direct GHG Emissions from Natural Gas Processing, Transportation and Distribution

The primary sources of GHG emissions involved in natural gas processing (operations) are:

- hydrocarbon or condensate extraction
- water extraction
- separation of liquefied natural gas
- extraction of hydrogen sulfide (H<sub>2</sub>S) and CO<sub>2</sub>
- liquid fraction present in natural gas
- capture of CO<sub>2</sub> extracted from natural gas for delivery outside the facility
- gathering or auxiliary stations and natural gas from multiple wellheads
- any other treatment process.

<sup>&</sup>lt;sup>73</sup> WSP, October 2015. Élaboration d'un projet type concernant les activités d'exploration et d'exploitation du pétrole et du gaz à Anticosti (Sample project preparation regarding oil and gas exploration and development activities in Anticosti). Study AENV17, https://mern.gouv.qc.ca/energie/filierehydrocarbures/etudes/AENV17.pdf.

<sup>&</sup>lt;sup>74</sup> SNC-Lavalin, 2013. Détermination des taux d'émission et modélisation de la dispersion atmosphérique pour évaluer l'impact sur la qualité de l'air des activités d'exploration et d'exploitation du gaz de schiste au Québec (Emission rate determination and air dispersion modelling to assess the impact of shale gas exploration and development on air quality in Quebec). http://www.bape.gouv.qc.ca/sections/mandats/gaz\_de\_schiste-enjeux/documents/PR3.6.18.pdf.

For all these sources, annual emissions of CH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub>O can be determined using Protocol <u>QC.33 of</u> the RMRCECA.

Natural gas transportation and distribution activities emit mainly CH<sub>4</sub> and, to a lesser extent, CO<sub>2</sub> and N<sub>2</sub>O. The emission sources targeted in the operational phase are all the processes and equipment used to transport and distribute natural gas. The main sources include:

- compression of natural gas for land transportation
- storage of natural gas and liquefied natural gas (LNG)
- import and export of LNG
- natural gas transmission pipelines
- natural gas distribution
- flares associated with the transmission and distribution system.

Annual emissions of CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub>O can be determined using Protocol QC.29 of the RMRCECA.

Recent advances have shown that fugitive methane emissions could be more significant than initially anticipated. This is why several countries, including Canada, have decided to establish a specific framework for this issue. In 2020, the Canadian government adopted the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)<sup>75</sup>. In addition to GHGs, these regulations also aim to control emissions of volatile organic compounds (VOCs) that are found with methane. Thus, fugitive methane emissions must be clearly identified and detailed in the calculations. If no formula provided by RMRCECA allows for an exhaustive calculation, another methodology can be used. The RMRCECA also lists several alternative methodologies, such as the one published by Clearstone Engineering Ltd. or the Canadian Gas Association's methodology. When appropriate, the methodology should be detailed and based on reliable and verifiable assumptions. For example, it may be possible to use emission factors per kilometre of pipe from existing networks in Quebec, based on the type of pipe material and gas pressure. In the absence of local data, IPCC emission factors can be used.<sup>76</sup>

For emissions in the construction phase, refer to <u>sections 1.9</u> and <u>1.10</u> on stationary and mobile combustion systems.

**NOTE:** Indirect emissions from natural gas pipeline transportation are presented in <u>section 1.36 on</u> Indirect Upstream or Downstream Emissions Attributable to Certain Projects.

# 1.35 Direct GHG Emissions from Liquid Hydrocarbons Transportation by Pipeline

Direct emission sources during the operational phase are related to all processes and equipment used for transportation and distribution. Table 40 in the previous section presents the different activities that can take place during the transportation of hydrocarbons by pipeline and provides the related quantification references. Several of the calculation methods refer to the RMRCECA or the American Petroleum Institute (API) guide. Due to the variability of activities and since the list provided is not necessarily exhaustive, the

<sup>&</sup>lt;sup>75</sup> Canada's methane regulations for the upstream oil and gas sector – Canada.ca. <u>https://www.canada.ca/en/environment-climate-change/services/canadian-</u> environmental-protection-act-registry/proposed-methane-regulations-additional-information.html

<sup>&</sup>lt;sup>76</sup> IPCC, 2019. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2\_Volume2/19R\_V2\_4\_Ch04\_Fugitive\_Emissions.pdf

emission sources and calculations must be detailed for each activity. If there is no formula provided in Table 40 that allows for a comprehensive calculation, an alternative methodology may be used. If so, the methodology must be detailed and based on reliable and verifiable assumptions.

For emissions in the construction phase, refer to <u>sections 1.9</u> and <u>1.10</u> on stationary and mobile combustion systems.

**NOTE:** Indirect emissions attributable to the transportation of hydrocarbons by pipeline are presented in Section on 1.36 on Indirect Upstream or Downstream Emissions Attributable to Certain Projects.

# **1.36 Indirect Upstream or Downstream Emissions Attributable to Certain Projects**

Those types of emissions, as previously mentioned in the general concepts in <u>Section 1.2.3</u>, belong to a different category of GHG emissions than those presented in the previous sections. They differ in that they are neither generated within the project nor controlled by the project owner. These emissions can be generated "upstream" or "downstream" of a project or "over the life cycle."

When is it required to consider upstream or downstream indirect emissions? It depends on each case.

Example 1: To achieve social acceptability, a project conducted within Quebec may require an upstream GHG emissions assessment if citizens or organizations are concerned that it may cause damage outside of Quebec. Take for example a hypothetical case of a biodiesel production plant in Quebec, where one of the raw materials used would be palm oil obtained through clear-cutting in Asia.

Example 2: Downstream indirect emissions can be especially relevant to transportation projects, whether it be to know the emissions from additional users once the project is completed (e.g., new highway) or those that the project will help avoid in the future (e.g., public transit or modal shift, decreased road congestion, etc.).

The following sections provide examples of how indirect upstream or downstream emissions attributable to specific projects can be calculated. The life cycle assessment approach is also presented.

## 1.36.1 Upstream GHG Emissions from Hydrocarbon Pipeline Projects

The calculation of GHG emissions can be done using one of the two methodologies presented below. The use of another methodology must be supported by appropriate justifications and detailed references.

# 1.36.1.1 Methodology for Calculating Upstream Emissions Proposed by Environment and Climate Change Canada (ECCC)

According to ECCC's approach<sup>77</sup>, the upstream GHG assessment consists of two parts: (A) a quantitative estimate of GHG emissions associated with the project; and (B) an assessment of the potential impact of the project on Quebec, Canadian and global GHG emissions. For the purposes of an assessment in Quebec, only part (A) is required. Part (B) is optional.

<sup>&</sup>lt;sup>77</sup> Environnement and Climate Change Canada-ECCC, 2016. Estimating upstream GHG emissions. <u>https://gazette.gc.ca/rp-pr/p1/2016/2016-03-19/html/notice-avis-eng.html</u>

The quantitative GHG estimate (A) will focus on emissions from upstream activities exclusively associated with the project. This estimate will consider emissions from combustion, fugitive emissions, venting, and flaring. It will not consider indirect emissions such as those associated with equipment manufacturing, land use change, grid electricity, and fuels produced elsewhere, unless they are indistinguishable from upstream emissions.

**(Optional)** Discussion component (B) will assess the conditions under which the upstream emissions estimated in Part A may occur even if the project is not carried out. This may require an assessment of projected hydrocarbon production with and without the project, under different price scenarios, possible transportation scenarios and "alternative" markets, costs, and other Canadian and global market conditions. The discussion will also explore the potential impact of GHG emissions associated with the project on GHG emissions in Quebec, on overall emissions in Canada, and, where possible, on global GHG emissions.

For example, for a hydrocarbon pipeline project, which requires an upstream GHG emissions assessment, see the equations in the referenced ECCC document available on the ECCC website (https://gazette.gc.ca/rp-pr/p1/2016/2016-03-19/html/notice-avis-eng.html).

# 1.36.1.2 Calculation Methodology based on the Estimated Intensity of GHG Emissions from Upstream Oil and Gas Operations

GHG emissions intensity can be expressed in grams of CO<sub>2</sub> equivalent per megajoule of energy produced, kilograms of CO<sub>2</sub> equivalent per barrel of oil equivalent, kilograms of CO<sub>2</sub> equivalent per cubic metre of natural gas, etc. In the literature, several studies present the intensity of GHG emissions from the production of "conventional" and "unconventional" hydrocarbons. By estimating the proportion of each type of hydrocarbon transported by the pipeline, it is possible to calculate the GHG emissions upstream of the project. The calculation methodology used must be detailed and based on reliable and verifiable assumptions.

## 1.36.2 Modal Shift in Passenger and Freight Transport and Reduction of Associated GHG Emissions

Modal shift refers to the "shifting" of travel modes from one mode of transport to another that could be potentially more economical in terms of GHG emissions. Transportation projects can influence the mode of transportation chosen by users.

## 1.36.2.1 Modal Shift in Passenger Transport

Structural public transport projects<sup>78</sup> have a proven impact on the modal shift from cars to public transport. This leads to benefits such as:

- Savings on vehicle use and parking costs
- A reduction in road congestion
- An improvement in road safety
- A reduction in GHG emissions and other pollutants from car traffic

However, the efficiency of the modal shift depends on multiple factors linked to the public transit supply, including:

<sup>&</sup>lt;sup>78</sup> A structuring public transport is a transport network which plays a determining role in the organization of the territory and urban mobility

- Quality of service: this includes punctuality, frequency, reliability and comfort of vehicles. These factors have a direct influence on user satisfaction and service attractiveness
- Accessibility: the proximity of the network access points to the population and jobs
- Intermodality: the ease of combining public transport with other modes of travel (bicycle, walking, carpooling)
- Social impact: improving quality of life, public health and mobility equity
- Operational efficiency: this includes measures such as cost per passenger carried, vehicle occupancy rate and commercial speed
- Implementation of real-time information systems.

Therefore, public transport projects can be an interesting way to encourage the population to change their mode of transportation, reducing the carbon footprint – since public transport produces less GHG emissions per passenger and per kilometre than individual cars.

The modal shift rate of a transportation project is generally calculated by analysing the distribution of the use of different transportation modes by comparing a reference scenario without the project and a scenario with the implementation of the project.

Several methods exist to estimate the modal shift rate:

- Extraction from a regional transportation model
- Measurements from a user survey
- Default values based on the population served (by comparison with transfer rates obtained in other regions with similar characteristics).

Therefore, once the reduction in car travel or trucking resulting from the project has been determined, it is possible to estimate the reduction in GHG emissions from the modal shift achieved by the project. The reduction in GHG emissions associated with the modal shift resulting from the project can be determined from Equation 44<sup>79</sup>.

#### Equation 44: GHG Emissions from Project Impacts on Modal Shift

$$ER_{GHG_PT} = Passenger_km(km/year) \times t_{TM}(\%) \times t_{FC}\left(\frac{l}{km}\right) \times EF_{fuel}\left(\frac{kgCO_{2e}}{l}\right) \times 0.001$$

Where:

 $ER_{GHG_{PT}}$  = Reduction of GHG emissions from passenger transportation, expressed in tonnes of CO<sub>2</sub> equivalent per year

Passenger\_km = Total distance travelled by passengers per year, expressed in kilometres per year  $t_{MS}$  = Modal shift rate (%)

*t*<sub>FC</sub> = Average fuel consumption rate of cars, expressed in litres per kilometre

 $EF_{fuel}$  = Emission factor associated with fuel, expressed in kilograms of CO<sub>2</sub> equivalent per litre 0.001 = Conversion factor from kilograms to tonnes

<sup>&</sup>lt;sup>79</sup> Golder Associates. Rapport de quantification des émissions de GES évitées par le transport collectif dans la région métropolitaine de Montréal (Quantification report on GHG emissions avoided through public transit in the greater Montreal area). November 2016.

#### 1.36.2.2 Indirect Emissions from Various Modes of Freight Transportation (truck, train, and ship)

If a project results in a change in freight transportation patterns, the indirect GHG emissions (or reductions) can be calculated by determining the difference between the GHG emissions of the freight transportation scenario proposed by the project (future scenario) and the freight transportation scenario without the project (current scenario).

Equation 45, developed by Natural Resources Canada (NRCan), calculates the difference between the freight GHG emissions associated with the project and those of the current scenario.

Equation 45: Indirect Emissions from Project Impacts on Freight Transportation

 $\Delta E_{PMS} = E_{PFT} - E_{CFT} = \left[ \left( t_{truck} \times d_{truck} \times EF_{truck} + t_{rail} \times d_{rail} \times EF_{rail} + t_{ship} \times d_{ship} \times EF_{ship} \right)_{p} - \left( t_{truck} \times d_{truck} \times EF_{truck} + t_{rail} \times d_{rail} \times EF_{rail} + t_{ship} \times d_{ship} \times EF_{ship} \right)_{BFP} \right] \times 0,001$ 

Where:

 $\Delta E_{PMS}$  = Change in GHG emissions attributable to the project's modal shift impacts in the freight sector, expressed in tonnes of CO<sub>2</sub> equivalent per year

 $E_{PFT}$  = Freight transportation GHG emissions expected after project implementation, expressed in tonnes of CO<sub>2</sub> equivalent per year

 $E_{CFT}$  = GHG emissions from freight transportation in the current scenario (before project implementation), expressed in tonnes of CO<sub>2</sub> equivalent per year

P = Scenario with project

BFP = Scenario before the project

*t*<sub>*truck*</sub> = Total annual tonnage transported by truck

*t<sub>rail</sub>* = Total annual tonnage transported by train

tship = Total annual tonnage transported by ship

*d*<sub>truck</sub> = Total annual trucking distance, expressed in kilometres

*d*<sub>rail</sub> = Total annual distance of transport by train, expressed in kilometres

*d*<sub>ship</sub> = Total annual distance of transport by ship, expressed in kilometres

 $EF_{truck}$  = Emission factor associated with trucking, expressed in kilograms of CO<sub>2</sub> equivalent per tonne per kilometre

 $EF_{rail}$  = Emission factor associated with rail transportation, expressed in kilograms of CO<sub>2</sub> equivalent per tonne per kilometre

 $EF_{ship}$  = Emission factor associated with shipping, expressed in kilograms of CO<sub>2</sub> equivalent per tonne per kilometre

Table 41 presents GHG emission factors associated with different modes of freight transportation.

Table 41. GHG Emission Factors Associated with Different Modes of Freight				
Transport, in Kilograms of CO <sub>2</sub> equivalent per Tonne Transported per Kilometre				
Mode of	Emission Factor Source: Natural Resources Canada			
Transportation	Transportation (kg CO <sub>2</sub> eq./tkm*)			
Truck	0.1873			
Rail	0.0191	GHGenius, version 4.03 or later, "Freight Emissions" page.		
Ship	0.0057			

\*Tonne-kilometre of transportation

#### 1.36.3 Indirect Emissions or Emission Reductions due to Traffic Flow and Road Congestion

The methodologies presented in this section can be applied in two different contexts. In the first, the calculations are used to assess the additional emissions induced by a road project if there is an increase in light and heavy vehicle flows. In the second context, the same methodologies are used to assess the reduction in GHG emissions attributable to a transportation project if there is a decrease in traffic flow (public transit, dedicated lane, etc.). In other words, the same methodologies can be applied in both contexts, but, depending on the case, they will be used to calculate emissions or reductions.

Some road projects modify the flow and performance of roadway systems. Tools based on GHG emission models through a representation of the transportation supply and demand system, at a given territory scale, help paint a picture of the impact of a project on GHG emissions from the movement of people.

The drivers of GHG emissions from road projects can be grouped into two main categories:

- Fleet data: vehicle types (passenger cars, light-duty vehicles, heavy trucks, two-wheelers, etc.), engines and fuels (gasoline, diesel, or electric, etc.), equipment, age of the fleet, and so on.
- Conditions of use (traffic data): annual distance traveled, average trip length, networks used (which may affect traffic speeds), weather conditions, driving behavior, etc.

Using fleet and traffic data, it is possible to model current and future GHG emissions.

It should also be mentioned that traffic congestion significantly influences vehicle fuel consumption. Therefore, transportation projects that may impact traffic congestion must consider the increase in fuel consumption due to congestion. This last category of emissions can be important in cities where traffic congestion is already high. Several models and approaches have been designed to determine the relationship between the level of congestion and GHG emissions<sup>80,81 et 82</sup>.

It should be noted that the estimation of GHG emissions from traffic flow and congestion are no longer required by the American Public Transportation Association (APTA). Therefore, it is left to those making the estimate to demonstrate whether it is necessary to take them into account or not.

<sup>&</sup>lt;sup>80</sup> APTA Climate Change Standards Working Group. Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit. APTA 2009. http://www.apta.com

<sup>&</sup>lt;sup>81</sup> INRIX GLOBAL TRAFFIC SCOREBOARD 2023. <u>http://inrix.com/scorecard//</u>

<sup>&</sup>lt;sup>82</sup> MOVES2014a (Motor Vehicle Emission Simulator). USEPA. <u>https://www.epa.gov/moves</u>

To model road traffic and resulting GHG emissions, the "Direction de la modélisation des systems de transport (DMST)" of the ministère des Transports et de la Mobilité durable (MTMD) uses the following sequence:

- Data collection and management (through origin-destination surveys)
- Road modeling using EMME<sup>83</sup> software, for macroscopic road simulation and MOVES 2<sup>84</sup> for GHG emissions quantification
- Public transportation modelling with MADITUC<sup>85</sup> software.

The three models mentioned above are established as references in this area and are therefore recommended for quantifying the emissions of these sources.

## 1.36.3.1 Indirect Emissions Associated with Urban Sprawl or Urban Densification

With the current state of knowledge, it is not yet possible to confidently estimate GHG emissions associated with urban sprawl or urban densification. Generally, the impacts of urban sprawl or densification projects can only be estimated for road or public transport projects of a certain scale. As knowledge is quickly expanding, if reliable, rigorous and well-documented methods can be used to estimate the impact of commuting on urban sprawl, an assessment of the resulting GHG emissions should be presented. This assessment should include a thorough description of the methodology and present detailed calculations with supporting assumptions and references.

## 1.36.4 Life Cycle Assessment

Life cycle assessment (LCA) is a methodology used to evaluate a product or service's environmental impacts during all or a part of its life cycle. This encompasses all the steps from extraction and transportation of raw materials to manufacturing, distribution, consumption or use, and ultimately disposal (including the reuse and recycling phases, if applicable). The LCA approach is illustrated below.

<sup>83</sup> Logiciel EMME. https://www.bentley.com/software/openpaths/

<sup>&</sup>lt;sup>84</sup> MOVES2014a. <u>https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves</u>

<sup>&</sup>lt;sup>85</sup> <u>https://www.madituc.polymtl.ca/</u>



Figure 4. Simplified Diagram of Life Cycle Assessment Steps

Source : adapted from the International Reference Centre for Life Cycle Assessment and Sustainable Transition (CIRAIG) (https://ciraig.org/index.php/life-cycle-assessment/).

Applied to the field of GHG emissions, LCA makes it possible to estimate the carbon footprint of a product or service. As an example, the carbon footprint based on the LCA of different fuels and combustibles used in Canada is presented in the following section.

#### 1.36.5 Carbon Footprint of Fuels used in Canada

This section presents the carbon footprint, expressed in terms of carbon intensity (CI), of different fuels used in Canada, assessing GHG emissions at different stages of the life cycle, as illustrated in Figure 5.





According to Figure 5, depending on the life cycle stage of the fuel, two types of CI values can be calculated:

- Well-to-gate<sup>86</sup> CI: This CI value includes emissions at the life cycle stages of feedstock production and transport, as well as fuel production at the plant
- Well-to-wheel CI: This CI value is also referred to as the CI value for the full life cycle of the fuel. In addition to the life cycle stages included in the well-to-gate CI, the well-to-wheel CI value also includes emissions from the distribution and combustion stages of the fuels.

Table 42 shows the CIs, expressed in grams of CO<sub>2</sub> equivalent per MJ, for most fuels produced or distributed in Canada. For liquid fossil fuels, the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) version 2.0 model was used to estimate GHG emissions from the extraction, processing, and transportation of crude oil. The natural gas CI was estimated using a weighted average based on natural gas production in Alberta and British Columbia and natural gas imported from the United States.

Table 42. Carbon Intensity (CI) of Fuels Produced or Distributed in Canada.					
Expressed in grams of CO <sub>2</sub> equivalent per MJ					
Fuel	Fuel Total CI from Cradle to Gate Total CI from Cradl				
	Grave (mean value)				
Biodiesel, camelina	16	16			
Biodiesel, canola	24	24			
Biodiesel, yellow grease	7.6	7.6			
Biodiesel, soy	29	29			
Biodiesel, beef tallow	21	21			
Bioethanol	45	45			
Non-marketable round wood, dry basis	6.9	6.9			
Aviation fuel	19	88			
Coal	6.5	100			
Petroleum coke	22	101			
Wood chips, dry basis	6.9	6.9			

<sup>&</sup>lt;sup>86</sup> The term "gate" refers to the gate of the production plant.

Table 42. Carbon intensity (Ci) of Fuels Produced of Distributed in Canada.			
Expressed in grams of CO <sub>2</sub> equivalent per MJ			
Fuel	Total CI from Cradle to		
	(mean value)	Grave (mean value)	
Diesel	25	96	
HPRD, canola <sup>87</sup>	54	54	
HRDC, palm oil <sup>88</sup>	24	24	
Gasoline	24	96	
Cellulosic ethanol, corn stover	-6.4	-6.4	
Cellulosic ethanol, wheat straw	-8.8	-8.8	
Ethanol, corn	42	42	
Natural gas	15	65	
Compressed natural gas (CNG)	19	67	
Liquefied natural gas (LNG)	27	77	
Liquefied petroleum gas (LPG)	16	83.6	
RNG, anaerobic digestion of organic matter	26	26.3	
RNG, landfill	5.9	6.2	
Wood pellets, dry basis	20.9	20.9	
Kerosene	19	87	
Fuel oil, light	24	95	
Fuel oil, heavy	23	98	
Fuel oil for stoves	24	92	
Propane	16	75	

Source: Fuel Life Cycle Assessment (LCA) Model. ECCC (2021)

# 1.37 Emissions from Black Carbon

Black carbon is an aerosol (airborne particles) emitted during the combustion process that has a short atmospheric lifetime and has global warming and health effects (refer to Appendix E). Black carbon is not emitted on its own; it is part of particles with a diameter of 2.5 microns or less (PM<sub>2.5</sub>), along with other components.

In 2015, the Ministers of the Arctic Council developed and adopted the Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions. This framework includes an engagement for all Arctic States to develop and improve black carbon emissions inventories using relevant guidelines from the Convention on Long-range Transboundary Air Pollution (CLRTAP). Subsequently, in 2017, all Arctic Council States declared a commitment to reduce black carbon emissions by 25 to 33% below 2013 levels by 2025.

In accordance with the Framework for Action, since 2016, Canada has conducted an annual inventory of Canada's black carbon emissions. Note that all emissions reported in the inventory are from anthropogenic sources. Natural sources of black carbon, such as forest fires, are excluded.

To this date, black carbon emissions are not accounted for in national GHG emissions inventories under the United Nations Framework Convention on Climate Change (UNFCCC). However, the climate impact of black

<sup>&</sup>lt;sup>87</sup> Renewable diesel produced by hydrogenation

<sup>&</sup>lt;sup>88</sup> Without taking into account land use change

carbon emissions is very significant. According to some researchers, black carbon is considered the second most important anthropogenic source of global warming, after CO<sub>2</sub><sup>89</sup>.

In 2022, approximately 26,000 tonnes of black carbon were emitted in Canada<sup>90</sup>. The main categories of black carbon emissions are presented in Table 43.

Table 43. Canadian Black Carbon Emissions in 2022			
Sector	Black Carbon Emissions in Tonnes		
Transportation and mobile equipment	13,000		
Commercial, Residential and Institutional (CRI)	8,400		
Oil and Gas Industry	2,600		
Ore and Mineral Industries	1,300		
Manufacturing	340		
Electric Power Generation (Utilities)	160		
Agriculture	25		
Total Emissions	26,000		

Source : Canada's Black Carbon Inventory Report 2013-2022.

Approximately 50% of all black carbon emissions in Canada are from the Transportation and Mobile Equipment category, of which off-road diesel equipment accounts for 7,700 tonnes or 30% of Canada's total black carbon emissions, while diesel engines used for on-road transportation are the other major source in this category, generating 2,200 tonnes per year or 8.4% of emissions.

The second largest source of black carbon in Canada is Fuel Combustion in the Commercial, Residential and Institutional (CRI) category. In 2022, the sector generated 8,100 tonnes of black carbon, representing 31% of Canada's total emissions. Within this category, Residential Wood Combustion is the largest contributor to emissions, accounting for 6,900 tonnes of black carbon, or 27% of Canada's total emissions.

Since 2013, Canada's black carbon emissions have decreased by 11,000 tonnes (31%). As a result, Canada has already met its share of the Arctic Council target of reducing black carbon emissions by 25 to 33% below 2013 levels by 2025. This decrease could be mainly attributable to the modernization of the off-road equipment fleet, a greater proportion of which complies with the most recent exhaust emission standards and, for sources related to residential wood combustion, the decrease in black carbon emissions is consistent with increasingly warm winters and some improvement in wood combustion equipment.

In Quebec, black carbon emissions in 2022 totaled 5,100 tonnes. Unlike Canada, the main source of black carbon emissions in Quebec is Residential Wood Combustion followed by the Transportation and Road Equipment category. Black carbon emissions in Quebec between 2013 and 2022 followed a similar trend to the one observed in Canada, decreasing by 34% during that period. Table 44 shows black carbon emissions in Quebec in 2022.

<sup>&</sup>lt;sup>89</sup> Greene S., Smart Freight Centre Adviser. Black Carbon Methodology for the Logistics Sector. <u>https://www.ccacoalition.org/en/resources/black-carbon-methodology-logistics-sector</u>

<sup>90</sup> Canada's Black Carbon Inventory Report 2013-2022. https://publications.gc.ca/collections/collection\_2024/eccc/En81-25-2024-eng.pdf

Table 44. Black Carbon Emissions in Quebec, in 2022		
Sector	Tonnes	
COMMERCIAL, RESIDENTIAL AND INSTITUTIONAL (CRI)	3 000	
Home Firewood Burning	2 900	
Fireplaces	520	
Furnaces	1 300	
Wood Stoves	1 100	
Fuel Combustion – Commercial and Institutional	120	
Fuel Combustion – Construction	15	
Fuel Combustion – Residential	6.5	
TRANSPORTATION AND MOBILE EQUIPMENT	1 800	
Off-Road Transport	1 100	
Diesel	1 000	
Gasoline, Liquid Petroleum Gas and Natural Gas	76	
On-Road Transport	450	
Diesel	320	
Gasoline	130	
Domestic Marine Navigation, Fishing and Military	110	
Rail Transportation	76	
Air Transportation (LTO)	26	
ORE AND MINERAL INDUSTRIES	140	
Mining and Rock Quarrying	99	
Aluminium Industry	34	
Foundries	7.9	
Cement and Concrete Industry	1.5	
ELECTRIC POWER GENERATION (UTILITIES)	49	
Diesel	28	
Other (Electric Power Generation)	21	
MANUFACTURING	45	
Pulp and Paper Industry	26	
Wood Products	19	
OIL AND GAS INDUSTRY	2.3	
Petroleum Liquids Transportation	2.1	
Natural Gas Transmission and Storage	0.17	
Natural Gas Distribution	0.04	
TOTAL	5 100	

Source: Canada's Black Carbon Inventory Report, 2013-2024.

<u>Appendix E – Complementary Information on Black Carbon</u> provides more detail on black carbon and its impacts. This section will focus on quantifying the associated GHG emissions.

For the calculation of black carbon emissions, two important assumptions are made: 1) black carbon is emitted primarily as PM<sub>2.5</sub>; and 2) only PM<sub>2.5</sub> emissions from combustion contain a significant amount of black carbon. Therefore, black carbon emissions are calculated by the amount of PM<sub>2.5</sub> emitted from the combustion process, multiplied by the proportions of black carbon specific to each source.

Diesel engines have both significant PM<sub>2.5</sub> emission rates and relatively high proportions of black carbon in these PM<sub>2.5</sub>. They are, therefore, one of the major sources of black carbon emissions. Other combustion

sources with high PM<sub>2.5</sub> emissions include solid fuel combustion units such as coal and wood boilers and residential combustion equipment (fireplaces, wood stoves, etc.).

The commercial-, residential-, and institutional-sector black carbon emission sources include firewood burning and fossil fuel burning in commercial establishments, institutional establishments, and homes.

The transportation and mobile equipment category includes air, marine, road, off-road, and rail transportation. On-road and off-road diesel engines are the largest source of black carbon emissions in this category.

In terms of methodology for calculating black carbon emissions, this guide follows the recommendations from the report "North American Black Carbon Emissions Estimation Guidelines: Recommended Methods for Estimating Black Carbon Emissions," developed in November 2015 by the Commission for Environmental Cooperation (CEC)<sup>91</sup>.

The guidelines adopt the three-tier structure used by the IPCC and adopted by the European practice community to establish best practices. In the IPCC and European inventory guidance documents (IPCC, 2006; EMEP/AEE, 2013<sup>92</sup>), these three tiers differ in the level of detail required for the activity and emission factors, and in the level of detail of the resulting inventory, with Tier 1 being the most general and Tier 3 being the most detailed. The tiers provide estimation options that depend on the available data and the purpose of the inventory. Typically, a Tier 1 method uses national fuel data and PM<sub>2.5</sub> and black carbon speciation factors are characterized by technology type. Tier 3 methods, where they can be applied, are generally considered the most accurate and are characterized by a much higher level of detail than the other two methods.

In general, these methods are based on an estimate of  $PM_{2.5}$  emissions, which is then converted to an estimate of black carbon emissions using a speciation factor. This speciation factor represents the fraction of  $PM_{2.5}$  that is black carbon, and its value depends on the fuel type and technology used.

Tier 1 and Tier 2 calculation methods are suggested in this guide.

<sup>&</sup>lt;sup>91</sup>http://www.cec.org/files/documents/publications/11629-north-american-black-carbon-emissions-recommended-methods-estimating-black-en.pdf.

<sup>&</sup>lt;sup>92</sup> EMEP/AEE (European Monitoring and Evaluation Programme [ Cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe] and European Environment Agency). 2013. EMEP/EEA air pollutant emission inventory guidebook 2013. Technical report No 12/2013. Doi: 10.2800/92722. Online: www.eea.europa.eu/publications/emep-eea-guidebook-2013.

## 1.37.1 Black Carbon Emissions from Stationary Combustion Systems

Stationary combustion systems generating black carbon emissions are used for the following purposes: power generation; oil and natural gas production, processing and refining; and manufacturing (including systems employing stationary diesel engines and industrial, commercial, and institutional boilers).

Fine particles (PM<sub>2.5</sub>) and black carbon are emitted into the atmosphere as a result of the use of different types of fuels (coal, fuel oil, diesel, natural gas, LPG, biomass, etc.).

Black carbon emissions from stationary combustion systems are estimated based on the activity's fuel consumption multiplied by a PM<sub>2.5</sub> emission factor per unit of fuel consumed, as well as a speciation factor that converts PM<sub>2.5</sub> emissions to black carbon emissions.

#### 1.37.1.1 Tier 1 Calculation of Black Carbon Emissions from Stationary Combustion Systems

The Tier 1 method estimates black carbon emissions based on fuel consumption and a default emission factor determined according to the type of fuel used in the industry. The Tier 1 method is based on Equation 46 below.

#### Equation 46: Black carbon emissions from stationary combustion sources (Tier 1)

$$E_{BC} = \sum_{i,j} (Q_{i,j} \times EF_{i,j,PM2,5} \times SF_{i,j,BC/PM2,5}) \times 0,001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from fuel combustion, in kilograms per year i = Type of fuel j = Type of industry  $Q_{i,l}$  = Quantity of fuel type i consumed annually in industry j  $EF_{i,j,PM2.5}$  = PM<sub>2.5</sub> emission factor associated to fuel "i" and industry "j"  $SF_{i,j,BC/PM2.5}$  = Speciation factor to convert PM<sub>2.5</sub> to black carbon for fuel type i 0.001 = Conversion factor from grams to kilograms

Table 45 and Table 46 present Tier 1 PM2.5 emission factors and speciation factors associated with different fuel types used in stationary combustion systems.

At the time of publication of this guide, a compilation of Tier 2 PM<sub>2.5</sub> emission factors was not available for stationary combustion systems. However, if such factors are available for a specific type of technology, the user could perform the Tier 2 black carbon emissions calculation according to Equation 47.

Table 45. Emission factors (EF <sub>i,i,PM2.5</sub> ), Tier 1				
Fuel	Emission	EFi,I,PM2.5	Units	Reference
	source			
Bituminous/sub-bituminous coal	Electricity	2,820.0	g <sub>PM2.5</sub> /tonne	(1)
Oil distillate	generation	185.8	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Lignite		236.2	g <sub>PM2.5</sub> /tonne	(1)
Liquefied petroleum gas (LPG)		101.6	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Natural gas		0.122	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Solid waste		17.5	g <sub>PM2.5</sub> /GJ	(1)
Wood waste		5,000.0	g <sub>PM2.5</sub> /tonne	(1)
Low-sulfur diesel		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Ultra-low-sulfur diesel		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Light fuel oil		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Heavy fuel oil		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Bituminous/sub-bituminous coal	Industrial	2,820.0	g <sub>PM2.5</sub> /tonne	(1)
Oil distillate		185.8	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Kerosene/naphtha (jet fuel)		4.8	g <sub>PM2.5</sub> /GJ	(1)
Lignite		337.4	g <sub>PM2.5</sub> /tonne	(1)
Liquefied petroleum gas (LPG)		132.5	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Natural gas		0.122	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Process gas/refinery gas		0.139	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Process gas/blast-furnace gas		0.138	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Process gas / coke oven gas		0.143	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Wood waste		5,000.0	g <sub>PM2.5</sub> /tonne	(1)
Low-sulfur diesel		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Ultra-low-sulfur diesel		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Light fuel oil		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Heavy fuel oil		30	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Anthracite and lignite	Commercial -	398	g <sub>PM2.5</sub> /GJ	(3)
Oil distillate	Residential -	47.9	g PMFiltrables/m <sup>3</sup> (*)	(1)
Kerosene	Institutional	47.9	g PMFiltrables/m <sup>3</sup> (*)	(1)
Natural gas		0.1	g <sub>PM2.5</sub> /m <sup>3</sup>	(1)
Wood		17,300.1	g <sub>PM10</sub> /tonne (**)	(1)
Light fuel oil	]	99.5	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)
Heavy fuel oil		99.5	g <sub>PM2.5</sub> /m <sup>3</sup>	(2)

(\*) No EF associated with PM2.5 for residential combustion of oil distillate and kerosene. Detailed PM fractions from the California Air Resources Board (CARB 2014) may be used.

(\*\*) No EF associated with PM<sub>2.5</sub> for residential wood combustion. Detailed PM fractions from the CARB (CARB 2014) may be used.

(1) WebFIRE (US EPA 2015b)

(2) ECCC 2021- Boiler and heaters emissions calculator: guide to reporting.
 (3) EMEP/AEE, 2013

Source: North American Black Carbon Emissions Estimation Guidelines. Part 3.2.

Table 46. Speciation Factors (SF), Tier 1				
Source/Fuel Type	Emission	EC (% mass)	Reference	
	Source			
Combustion of bituminous coal	Power and	1.696%	SPECIATE (US EPA	
Combustion of oil distillate	industrial	10%	2011)	
Combustion of lignite	production	1.43%		
Combustion of natural gas		38.4%		
Combustion of liquefied petroleum gas		38.4%		
(LPG)				
Combustion of process gases		14.57%		
Combustion of waste oil		1%		
Combustion of solid waste		1.52%		
Combustion of sub-bituminous coal		4.28%		
Combustion of wood/bark		3.3%	EMEP/AEE, 2013	
Low-sulfur diesel		10%	CBCIR*	
Ultra-low-sulfur diesel		10%		
Light fuel oil		10%		
Heavy fuel oil		10%		
Combustion of anthracite and lignite	Commercial -	6.4%	EMEP/AEE, 2013	
Combustion of natural gas	residential -	6.7%	SPECIATE (US EPA	
Combustion of petroleum	institutional	3.90%	2011)	
Combustion of wood		5.58%		
Light fuel oil		10%	CBCIR*	
Heavy fuel oil		1%		

Note: The speciation factor refers to the percentage of PM<sub>2.5</sub> that is elemental carbon (EC). Elemental carbon is recognized as a proxy for black carbon until improved measurement methods and data become available.

\*Canada's Black Carbon Inventory Report 2013-2019.

Source: North American Black Carbon Emissions Estimation Guidelines. Part 3.2.

#### 1.37.1.2 Tier 2 Calculation of Black Carbon Emissions from Stationary Combustion Systems

The Tier 2 method estimates emissions for each combination of fuel and technology types used. The Tier 2 methodology is based on Equation 47.

#### Equation 47: Black Carbon Emissions from Stationary Combustion Sources (Tier 2)

$$E_{CN} = \sum_{i,j} (Q_{i,j} \times EF_{i,j,PM2,5} \times SF_{i,j,CN/PM2,5}) \times 0,001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from stationary combustion systems, in kilograms per year

i = Type of fuel

*j* = Type of technology/equipment (e.g., natural gas-fired boiler, diesel engine, or oil-fired boiler)

*Q<sub>i,j</sub>* = Amount of fuel type "i" consumed annually in technology/equipment type "j"

EF<sub>i,I,PM2.5</sub> = PM<sub>2.5</sub> emission factor associated with fuel type "i" and industry "I"

SF<sub>i,I,BC/PM2.5</sub> = Speciation factor to be applied to convert PM<sub>2.5</sub> to black carbon for fuel type "i"

0.001 = Conversion factor from grams to kilograms

## 1.37.1.3 Estimating the Climate Impact of Black Carbon Emissions from Stationary Combustion Systems

Once the black carbon emissions have been determined, Equation 48 is used to estimate their impact on global warming.

Equation 48: Black Carbon Emissions from Stationary Combustion Sources (Tier 2)

$$E_{GHG_BC} = E_{BC} \times GWP_{100_BC} \times 0.001$$

Where:

 $E_{GHG_BC}$  = Annual GHG emissions from black carbon emissions attributable to stationary combustion systems, in tonnes of CO<sub>2</sub> equivalent per year

 $E_{BC}$  = Black carbon emissions from fuel combustion, in kilograms of black carbon per year GWP<sub>100\_BC</sub> = Black Carbon GWP over a 100-year time period (see Appendix E)

0.001 = Conversion factor from kilograms to tonnes

## 1.37.2 Calculation of Black Carbon Emissions from Mobile Combustion Systems

Mobile sources can be subdivided into five broad categories:

- On-road vehicles: cars, trucks, buses, motorcycles, etc.
- Off-road equipment: equipment used in construction, agriculture and industry (excavators, bulldozers, tractors, cranes, off-road trucks, graders, dump trucks, etc.)
- Rail transportation
- Marine transportation
- Aviation.

Because of the prevalence of diesel engines in most of these categories, mobile sources are among the largest emitters of black carbon.

## 1.37.2.1 Tier 1 Calculation of Black Carbon Emissions from On-road Mobile Sources

On-road mobile sources use a diverse range of fuels, including gasoline, diesel, ethanol fuels, liquefied petroleum gas (LPG), and compressed natural gas (CNG). The largest contributors to black carbon emissions from on-road mobile sources are by far heavy-duty diesel trucks. For these vehicles, incomplete combustion of long-chain hydrocarbons in diesel fuel is the main contributor to black carbon emissions.

Detailed inventories of PM<sub>2.5</sub> emissions from on-road vehicles are being conducted in Canada and the United States, and models have been developed to estimate the amount of PM<sub>2.5</sub> emitted per kilometre driven in the different vehicle categories. Of these models, the most widely used in North America today is the MOVES model, developed by the US EPA. This model has the advantage of incorporating a considerable amount of new data on PM<sub>2.5</sub> emissions from cars, light trucks, and heavy trucks that are more realistic than previous estimates and lead to more accurate estimates of total PM<sub>2.5</sub> emissions. In addition, MOVES produces direct estimates of elemental carbon (EC), which is a better proxy for black carbon than PM<sub>2.5</sub>.

The calculation of Tier 1 black carbon emissions from on-road mobile sources is based on the fuel consumption of the activity under consideration, multiplied by an EC emission factor specific to the fuel type. (Here, the EC emission factor is assumed to be the same as the black carbon emission factor.)

Equation 49 estimates black carbon emissions from mobile sources based on fuel type and consumption.

Equation 49: Black Carbon Emissions from On-road Mobile Sources (Tier 1)

$$E_{BC} = \sum_{i} (Q_i \times EF_{i,EC} \times 0.001)$$

Where:

 $E_{BC}$  = Annual black carbon emissions from on-road mobile sources, in kilograms per year

i = Type of fuel

Q<sub>i</sub> = Quantity of type "i" fuel consumed annually

EF<sub>i,EC</sub> = EC emission factor for fuel type "i" in grams per litre of fuel

0.001 = Conversion factor from grams to kilograms

Table 47 presents the EC emission factors associated with diesel and gasoline.

Table 47. Elemental Carbon Emission Factors for Diesel and Gasoline					
Fuel	Emissions Source	Pollutant	Factor	Units	Reference
Diesel	All Diesel Vehicles (Canada and United States)	EC	0.391	g/l	MOVES 2014
Gasoline	All Diesel Vehicles (Canada and United States)	EC	0.132	g/l	MOVES 2014

Source: North American Black Carbon Emissions Estimation Guidelines. Section 3.3.1.

## 1.37.2.2 Tier 1 Calculation of Black Carbon Emissions from Off-road Mobile Sources

Black carbon emissions from off-road mobile sources are primarily from the combustion of diesel fuel and, to a lesser extent, from the combustion of gasoline and other fuels such as LPG or natural gas. The off-road sources discussed in this section include fossil fuel-powered mining, agricultural, construction, logging and airport support equipment.

Annual black carbon emissions from off-road mobile sources can be calculated from the specific black carbon emission rate multiplied by the expected service life, based on Equation 50.

Equation 50: Annual Black Carbon Emissions from Off-road Mobile Sources (Tier 1)

$$E_{BC} = \sum_{i} \left( t_i \times P \times LF \times EF_{i,PM10} \times \frac{PM_{2.5}}{PM_{10}} \times SF_{BC} \right) \times 0.001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from off-road mobile sources

*i* = Type of off-road mobile source

 $t_i$  = Time of use per year of off-road mobile source *i*, expressed in hours per year

*P* = Power of mobile source, in kW

LF = Equipment load factor 93

 $EF_{i,PM10}$  = Emission factor for particulate matter less than 10 microns in diameter for mobile source type *i*, in grams per kW per hour <sup>94</sup>

 $PM_{2.5}/PM_{10}$  = fraction of particles smaller than 2.5 microns in diameter in proportion to total particles = 0.97<sup>95</sup>

 $SF_{BC}$  = Speciation factor to convert  $PM_{2.5}$  to black carbon for diesel fuel = 0.7897<sup>96</sup>

0.001 = Conversion factor from grams to kilograms

Table 48 shows the exhaust emission standards that establish a maximum level for emissions of particulate matter less than 10 microns in diameter from off-road equipment. The emission standards are divided into categories based on engine power and are defined as the mass of particulate matter per unit of power output expressed in grams per kilowatt-hour.

Table 48. PM <sub>10</sub> Emission Standards for Off-road Machinery					
Power (kW)	Tier	Model Years	PM (g/kWh)	Note	
kW<8	0	Prior to 2000	1		
	1	2000–2005	1		
	2	2006–2011	0.8		
	4	2012 +	0.4		
8 <kw<19< td=""><td>0</td><td>Prior to 2000</td><td>0.95</td><td></td></kw<19<>	0	Prior to 2000	0.95		
	1	2000–2005	0.8		
	2	2006–2011	0.8		
	4	2012 +	0.4		
19 <kw<37< td=""><td>0</td><td>Prior to 1999</td><td>0.95</td><td></td></kw<37<>	0	Prior to 1999	0.95		
	1	1999–2005	0.8		
	2	2006–2011	0.6		
	4	2012 +	0.03		
37 <kw<56< td=""><td>1</td><td>1998–2005</td><td>0.8</td><td></td></kw<56<>	1	1998–2005	0.8		
	2	2006–2007	0.4		
	3	2007–2011	0.3		
	4	2012 +	0.03		
56 <kw<75< td=""><td>1</td><td>1998–2005</td><td></td><td></td></kw<75<>	1	1998–2005			
	2	2006–2007	0.4		
	3	2007–2011	0.4		
	Interim 4	2012	0.02		

<sup>&</sup>lt;sup>93</sup> Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-compression-ignition, US EPA 2008, Appendix A, Table A4 and Appendix C, Table C2.

<sup>&</sup>lt;sup>94</sup> Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-compression-ignition, US EPA 2008, Appendix A, Tables A1 to A4 and Appendix C, Table C2.

<sup>&</sup>lt;sup>95</sup> Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-compression-ignition, US EPA 2008. Page 25.

<sup>&</sup>lt;sup>96</sup> Canada's Black Carbon Inventory 2013-2024. Table A2-5.

Table 48. PM <sub>10</sub> Emission Standards for Off-road Machinery					
Power (kW)	Tier	Model Years	PM (g/kWh)	Note	
	4	2013+	0.02		
75 <kw<130< td=""><td>1</td><td>1998–2005</td><td></td><td></td></kw<130<>	1	1998–2005			
	2	2006	0.3		
	3	2007–2011	0.3		
	4	2012 +	0.02		
130 <kw<560< td=""><td>1</td><td>1998–2005</td><td>0.54 +</td><td></td></kw<560<>	1	1998–2005	0.54 +		
	3	2006–2011	0.2		
	4	2012 +	0.02		
>560kW	1	1998–2005	0.54 +		
	2	2006–2011	0.2		
	Interim 4	2012–2014	0.1		
	4	2015 +	0.04 +	*All except gen-set drive engines	
	4	2015 +	0.03**	**Gen-set drive engines	

Source: Guidance document on Off-Road Compression-Ignition Engine Emission Regulations: chapter 6. (https://www.canada.ca/en/environmentclimate-change/services/canadian-environmental-protection-act-registry/publications/guidance-document-engine-emission-regulations/chapter-6.html)

#### 1.37.2.3 Calculation of Black Carbon Emissions from Locomotives

Black carbon emissions from locomotives are caused by the combustion of diesel fuel associated with passenger and freight rail transportation.

Annual black carbon emissions from locomotives can be estimated from annual diesel fuel consumption and a default emission factor established for locomotives. The calculation can be made using Equation 51.

#### Equation 51: Annual Black Carbon Emissions from Locomotives (Tier 1)

$$E_{BC} = Q \times EF_{PM2.5} \times SF_{BC/PM2.5} \times 0.001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from locomotives, in kilograms per year

Q = Amount of diesel fuel consumed annually, in litres

 $EF_{PM2,5} = PM_{2.5}$  emission factor = 1.204  $g_{PM2.5}/l^*$ 

SF<sub>BC/PM2.5</sub> = Speciation factor to be applied to convert PM<sub>2.5</sub> to black carbon for locomotives = 0.6767\*

0.001 = Conversion factor from grams to kilograms

\* North American Black Carbon Emissions Estimation Guidelines. Section 3.3.3

#### 1.37.2.4 Calculation of Black Carbon Emissions from Marine Vessels

Black carbon emissions from marine vessels are attributable to the combustion of diesel fuel or the combustion of residual fuel blends for marine transportation. Annual black carbon emissions from marine vessels can be estimated from annual fuel consumption and a default emission factor for ships. The calculation can be made using Equation 52.

Equation 52: Annual Black Carbon Emissions from Marine Vessels (Tier 1)

$$E_{BC} = \sum_{i} (Q_i \times EF_{i,PM2.5} \times SF_{i,BC/PM2.5}) \times 0.001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from marine vessels, in kilograms per year

*i* = Fuel type (*i.e.*, diesel or residual fuel blend)

*Q<sub>i</sub>* = Quantity of type "i" marine fuel consumed annually, in litres

*EF*<sub>*i*,*PM*2.5</sub> = *PM*2.5 emission factor associated with fuel type "i", in gPM2.5/l

SF<sub>i,BC/PM2.5</sub> = Speciation factor to convert PM<sub>2.5</sub> to black carbon for fuel type "i"

0.001 = Conversion factor from grams to kilograms

Table 49 presents PM<sub>2.5</sub> emission factors and speciation factors associated with the different types of fuels used in marine vessels.

Table 49. PM <sub>2.5</sub> emission factors and speciation factors associated with different fuel types used in marine vessels			
Fuel	EF <sub>i,PM2.5</sub> (gpm2.5/l)	SF <sub>i,BC/PM2.5</sub>	Reference
Diesel General blend of residual fuels for marine vessels	1.998 <sup>(1)</sup> 6.271 <sup>(2)</sup>	0.77 <sup>(3)</sup> 0.06 <sup>(3)</sup>	<ul> <li>US EPA Regulatory Impact Analysis (Category 1 and 2, EPA 2007; Category 3, EPA 2009c)</li> <li>International Maritime Organization (IMO) study on the reduction of GHG emission from marine vessels (2014)</li> <li>US EPA, 2013a</li> </ul>

Source: North American Black Carbon Emissions Estimation Guidelines. Section 3.3.4.

1.37.2.5 Calculation of Black Carbon Emissions from Aircraft

Black carbon emissions from aircraft are attributable to the combustion of jet fuel associated with passenger and freight transportation and other aviation activities.

Annual black carbon emissions from aircraft can be estimated from annual jet fuel consumption and a default emission factor. The calculation can be made using Equation 53.

#### Equation 53: Annual Black Carbon Emissions from Aircraft

$$E_{BC} = Q \times EF_{PM2.5} \times SF_{BC/PM2.5} \times 0.001$$

Where:

 $E_{BC}$  = Annual black carbon emissions from aircraft, in kilograms per year Q = Amount of fuel consumed annually, in litres  $EF_{PM2.5}$  = Jet fuel PM<sub>2.5</sub> emission factor = 0.164 g<sub>PM2.5</sub>/l\*  $SF_{BC/PM2.5}$  = Speciation factor to be applied to convert PM<sub>2.5</sub> to black carbon = 0.13\* 0.001 = Conversion factor from grams to kilograms \*North American Black Carbon Emissions Estimation Guidelines. Section 3.3.5.

## 1.38 Emissions from Activities not Presented in this Guide or Emerging Quantification Issues

If an activity not presented in this guide (e.g., CO<sub>2</sub> capture and sequestration<sup>97</sup>) is likely to emit GHGs, a GHG emissions assessment based on recognized methodologies and credible and verifiable assumptions must be conducted. The MELCCFP is always available to provide support for assessments.

As mentioned in the introduction, knowledge in the field of climate change is rapidly evolving, and some issues may be addressed in a future update of this guide. These issues include the concept of best available technology, GHG sequestration in wetlands, biological, chemical, and geological CO<sub>2</sub> capture and sequestration, deep geothermal power, carbon debt from forestry projects, and the development of a framework for life cycle assessments of certain projects.

# MITIGATION MEASURES FOR GHG EMISSIONS REDUCTION

# **1.39 Types and Examples of GHG Emissions Reduction Measures**

Mitigating GHG emissions is an essential action for the development of a sustainable project and is part of the quantification approach presented in this guide. Measures to reduce GHG emissions can be physical, organizational, or behavioral. Table 50 presents the main characteristics of each of these types. The selection of optimal GHG emissions reduction measures for each project should be guided by:

- The reduction in GHG emissions achieved by the implementation of the measure
- Applicability to the Quebec context
- Financial considerations.

<sup>97</sup>ISO 27914:2017 - Carbon dioxide capture, transportation and geological storage — Geological storage, https://www.iso.org/standard/64148.html.

Table	Table 50. Types of GHG Emissions Reduction Measures (Non-Exhaustive List)					
	MODIFICATION OF EQUIPMENT OR SYSTEMS. THIS TYPE OF MEASURE IS USUALLY					
	LINKED TO AN INV	/ESTMENT.				
	TECHNOLOGY	Use equipment or technologies that reduce energy consumption or use renewal energy with low GHG emissions. Examples:				
- MEASURES		<ul> <li>Use the best available technology from a techno-economic feasibility standpoint</li> <li>Use alternative energy sources with low carbon footprints</li> <li>Use more efficient equipment</li> <li>Replace combustion equipment with electric equipment</li> <li>Replace oil-fired boilers with residual biomass-fired boilers</li> <li>Use grid-connected equipment instead of generators when conditions permit</li> <li>For buildings, adopt green certification practices that help reduce energy consumption and GHG emissions. Use geothermal energy where possible</li> <li>Take advantage of existing funding programs to reduce GHG emissions</li> <li>Examine the feasibility of sustainable GHG capture and sequestration.</li> </ul>				
CA	PROCESSES	Optimize industrial production processes to minimize GHG emissions. Examples:				
ISYHA		<ul> <li>Minimize or eliminate sources of GHG emissions in industrial processes</li> <li>Implement energy efficiency measures that are sustainable over time and a continuous improvement process</li> <li>Optimize heat (or cold) recovery and reduce thermal waste</li> <li>Implement process integration (Pinch analysis)<sup>98</sup></li> <li>Replace HFCs in industrial refrigeration equipment with other refrigerants that are less emissive or have a low GWP</li> <li>Minimize SF<sub>6</sub> losses during operations</li> <li>Take advantage of existing funding programs to reduce GHG emissions</li> <li>Practise circular economy, i.e., use a company's waste materials as raw materials (e.g., sell the steam generated by a waste incinerator to a nearby industry).</li> </ul>				
	CHANGES IN ORGANI	ZATIONAL PROCESSES				
UIZATIONAL ASURES	SUSTAINABLE PURCHASING POLICY	<ul> <li>Integrate sustainable development criteria into the organization's purchasing policies.</li> <li>Examples:</li> <li>Establish specific GHG requirements in the company's raw material purchases, specifications, or performance requirements</li> <li>Buy locally</li> <li>Know the carbon footprint of products.</li> </ul>				
ORGAN ME/	FLOW OPTIMIZATION	<ul> <li>Optimize the flow of materials, people and goods to reduce related GHG emissions. Examples:</li> <li>Optimize passenger and freight transportation logistics through intermodal options (train, boat, truck)</li> <li>Use raw materials located closer to the site (e.g., borrow pit materials)</li> </ul>				

<sup>&</sup>lt;sup>98</sup> According to Canmet Energy (RNCan), process integration is a systemic approach to identify and remedy inefficiencies in industrial processes by analyzing interactions between operations as a whole, rather than individually. Process integration accounts for technical and financial constraints before detailed design. (Pinch analysis). https://www.nrcan.gc.ca/energy-efficiency/data-research-insights-energy-efficiency/commercial-industrial-innovation/industrial-systemsoptimization/process-integration-and-pinch-analysis/5497

Table	50. Types of GHC	Emissions Reduction Measures (Non-Exhaustive List)
		<ul> <li>Reduce empty returns in trucking</li> <li>Use transportation methods that emit less GHGs.</li> </ul>
	RESEARCH AND DEVELOPMENT	Conduct research and development to design products, materials, practices, or technologies that reduce GHG emissions in the way they are produced or used. Examples: • Eco-design • Design of processes that emit less GHGs.
	CHANGES IN EVERYD	AY BEHAVIOR
	INFORMATION AND AWARENESS	Inform and educate employees, suppliers, customers, and users on ways to reduce GHG emissions. Examples:
RES		<ul> <li>Carry out information or awareness campaigns</li> <li>Promote best practices for reducing GHG emissions.</li> </ul>
ASUF	TRAINING	Enable the various stakeholders to acquire good practices that promote energy savings or the reduction of GHG emissions. Examples:
ME		<ul> <li>Training on responsible waste management</li> </ul>
RAL		<ul> <li>Training on process integration, energy efficiency, renewable energy, etc.</li> <li>Training on circular economy</li> </ul>
IOU		<ul> <li>Training on fuel-efficient driving for employees.</li> </ul>
BEHAVI	VOLUNTARY COMMITMENTS OR AGREEMENTS	<ul> <li>Commit to voluntary GHG emissions reduction targets. Examples:</li> <li>Establish annual GHG emission intensity reduction targets per unit produced</li> <li>Establish a procedure to limit HFC emissions from refrigeration systems</li> <li>Establish a responsible energy consumption policy</li> <li>Contribute to third-party reduction measures (e.g., installation of electrical charging stations)</li> <li>Promote circular economy and industrial symbiosis.</li> </ul>

# 1.40 Quantification of GHG Emissions Reduction from Mitigation Measures

To quantify the reduction potential of a mitigation measure, the difference is calculated between the GHG emissions of the baseline scenario and the GHG emissions of the project including the proposed measure. The baseline scenario is defined as the scenario most likely to occur in the absence of mitigation measures. Typically, the baseline scenario represents business as usual or the current situation. Two examples are presented in Table *51* and 52.

Table 51. Example of reduction calculation for stationary combustion sources					
Emissions Source	Baseline Scenario	Proposed Scenario	GHG Emissions Reduction		
	(Oil-fired boiler, 75% efficiency)	(Oil-fired boiler, 90% efficiency)	(Baseline scenario minus proposed scenario)		
	GHG Emissions (tonnes CO₂ eq./yr)	GHG Emissions (tonnes CO <sub>2</sub> eq./yr)	(tonnes CO <sub>2</sub> eq./yr)		
Boiler	10,000	8,000	2,000		

Table 52. Example of Reduction Calculation for Mobile Combustion Sources					
Emission Source	Baseline Scenario	Proposed Scenario	GHG Emissions Reduction		
	(Borrow pit 40 km from the site)	(Borrow pit 10 km from the site)	(Baseline scenario minus proposed scenario)		
	GHG emissions (tonnes CO₂ eq./yr)	GHG emissions (tonnes CO₂ eq./yr)	(tonnes CO <sub>2</sub> eq./yr)		
Transport of materials by truck	50	20	30		

The preferred tools for determining reduction measures are the GHG emissions mitigation plan and the accompanying GHG monitoring plan. These tools are used to identify the most emissive activities and determine the mitigation measures to be taken, with quantification. Both are presented below.

# 1.41 GHG Emissions Mitigation Plan

## The GHG Emissions Mitigation Plan, A Lever for Internal Engagement

Experience shows that the implementation of such a plan is an excellent internal communication tool to engage stakeholders involved in the project around sustainable development goals shared by all. This plan can be part of a GHG management system or integrated into a pre-existing management system, whether it be an environmental (e.g., ISO 14001), quality (e.g., ISO 9001), or energy (e.g., ISO 50001) management system. This plan can help the organization to:

- Reduce its operating costs
- Innovate and stand out
- Improve its image
- Anticipate new constraints
- Prepare for changes in energy prices
- Motivate the team
- Act for the planet and the climate
- Establish new partnerships.

In concrete terms, when developing the mitigation plan, it is important to draw up a more or less exhaustive list of measures and select the most promising in terms of reducing GHG emissions, taking into account their technical and economic feasibility. It is important to adopt measures with a high potential for reducing GHG emissions, without neglecting those which, despite having a lower reduction potential, have a strong power to mobilize teams.

In particular, the plan should include:

- A description of the GHG emissions reduction measures planned for the different phases of the project
- A description of the baseline scenario and the proposed scenario
- A quantification of the GHG emission reductions attributable to the different measures. To perform the quantification, methodologies other than those proposed in this guide can be used to establish the baseline scenario and the scenario with the proposed measure (see examples in the tables in the previous section)
- An explanation of how GHG emissions reduction opportunities are incorporated into the design or subsequent operations of the project
- Where applicable, mitigation measures that would result in indirect GHG emission reductions or avoided emissions, along with their quantification (e.g., dedicated lane for public transit).

If it appears that mitigation measures with high reduction potential cannot be implemented for economic, social, or environmental reasons, this must be documented.

Monitoring the effectiveness of mitigation measures should be included in the GHG emissions monitoring plan, described below.

# 1.42 GHG Emissions Monitoring Plan

The monitoring plan makes it possible to quantify the GHG emissions generated by the project and to follow their evolution over time. In general, a monitoring plan indicates the type of data to be collected (e.g., fuel consumption, the process and methods for collecting this data, the frequency of data collection, etc.). It is intended to facilitate the quantification of GHG emissions and may evolve over the life of the project.

For an ongoing project submitted to the RMRCECA, the GHG emissions report is an excellent tracking tool. However, not all projects are subject to the RMRCECA, and this regulation does not cover construction emissions or post-closure emissions. In this context, the ISO 14064 standard and the GHG Protocol's Mitigation Goal Standard (World Resources Institute, 2018) can be used as references. An example of a GHG emissions monitoring plan is presented in <u>Appendix C – GHG Emissions Monitoring Plan.</u>

# 1.43 Avoided Emissions

Beyond reducing their own GHG emissions, companies and organizations can participate in the transition to a lower-carbon economy through the solutions they can develop. These solutions contribute to reducing emissions downstream of the value chain, in comparison with other existing and usual solutions.

The avoided emissions of a company, organization, or project refer to the emission reductions achieved by its activities, products, and/or services, when these reductions occur outside its scope of activity. These emissions are assessed against a baseline scenario as defined in <u>Section 1.40</u>.

Examples of avoided emissions are listed below:

- Production of renewable energy or steam from cogeneration, for the benefit of third parties
- Recovery of materials (recycling) or energy (energy recovery) from waste for the benefit of others
- Sale of products or services whose use reduces GHG emissions outside the scope of the project, company, or organization
- Financing of third-party projects that reduce GHG emissions outside the scope of the project, company, or organization
- Financing of third-party projects that increase carbon sinks outside the scope of the project, company, or organization
- Emissions avoided when the company or organization implements projects that contribute to reducing GHG emissions in the value chain (e.g., production of low-carbon intensity fuels, production of zero-emission vehicles, etc.)
## **MAIN REFERENCES**

Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere. <u>https://www.legisquebec.gouv.qc.ca/en/document/cr/Q-2,%20r.%2015</u>

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# **APPENDIX A – CHECKLIST OF GHG EMISSION SOURCES TO CONSIDER BY SECTOR**

Table 53. Checklist of GHG Emission Sources to Consider by Sector																						
	Project types and phases (C = Construction; O = Operation; D = Decommissioning or closure)																					
GHG emission sources	Guide section	Guide Industries section (Note 1)			Energy (Note 2)			Water (Note 3)			Agriculture (Note 4)			Transportation			Waste materials and contaminated soils			Hydrocarbons (Section 3.24)		
		C	0	D	С	0	D	С	0	D	С	0	D	С	0	D	С	0	D	С	0	D
Stationary combustion systems	1.9	Х	Х	Х	Х	х		Х				Х		Х	x		х	Х				
Mobile combustion	1 10	~	v	v	v	v	v	v	V3h	V <sub>3h</sub>	v	~		~	×	v	v	v	~	v	×	v
systems	1.10	^	^	^	^	^	^	^	<b>^</b> **	<b>N</b> 00	^	^		^	^	^	^	^	^	^	^	^
Electrical energy	1 1 1	X	x	x	x	x	x	x	x	<b>X</b> 3a	x	X		x	x		x	x		x	x	x
consumption	1.11	^	^	^	^	^	Λ	^	~	Non	^	^		^	^		^	~		^	^	
Industrial processes	1.12		Х																			
Mining and mineral	1.13		Х																			
processing																						ļ
Hydrogen production	1.14	Х	X	Х	Х	Х								Х	Х						Х	<u> </u>
Explosives use	1.16	Х	Х		Х			Х						Х			Х					
Fugitive emissions of																						
sulfur hexafluoride and	1.17					Х			$X^{3a}$													
perfluorocarbons																						
Refrigeration and air	1 18		Y	Y								Y			x							
conditioning equipment	1.10		^	^								^			^							
Deforestation	1.19	Х			Х			Х			Х			Х			Х			Х	Х	
Loss of wetlands	1.21	Х			Х			Х														
Flooding of ecosystems	1.23							X <sup>3a</sup>														
Agricultural production	0											Х										

Table 53. Checklist of GHG Emission Sources to Consider by Sector																						
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GHG emission sources	Guide section	Industries (Note 1)		Energy (Note 2)		Water (Note 3)			Agriculture (Note 4)			Transportation			waste materials and contaminated soils			Hydrocarbons (Section 3.24)				
		С	0	D	С	0	D	C	0	D	С	0	D	С	0	D	С	0	D	С	0	D
Landfill of waste materials	1.25																	Х	Х			
Biogas cleaning	1.26																	Х	Х			
Biogas destruction	1.27																	Х	Х			
Biomethanization of waste materials	1.28		X															Х				
Compression and liquefaction of biogas	1.29		Х															Х				
Composting of waste materials	1.30		Х															Х				
Waste incineration or thermal treatment of hazardous materials or contaminated soil	1.31																	х				
Wastewater treatment and discharge	1.32		Х															Х		Х	х	Х
Hydrocarbon exploration and development	1.33																			Х	х	Х
Natural gas processing, transportation and distribution	1.34					х														x	х	Х
Transportation of hydrocarbons by pipeline	1.35				Х	Х	Х													Х	Х	Х

Table 53. Checklist of GHG Emission Sources to Consider by Sector																						
	Project types and phases (C = Construction; O = Operation; D = Decommissioning or closure)																					
GHG emission sources	Guide section	Industries (Note 1)			Energy (Note 2)		Water (Note 3)		Agriculture (Note 4)			Transportation		ation	Waste materials and contaminated soils			Hydrocarbons (Section 3.24)				
		С	0	D	C	0	D	C	0	D	С	0	D	С	0	D	С	0	D	С	0	D
Indirect upstream emissions of hydrocarbon transportation by pipeline	1.36.1					x														x	х	х
Indirect emissions from modal shift	1.36.2														Х							
Indirect emissions from traffic flow and congestion	1.36.3								X <sup>3b</sup>						x							
Indirect emissions from different modes of freight transportation	1.36.2								X <sup>3b</sup>						x							
Life cycle analysis	1.36.4																			Х	Х	Х
Black carbon	1.37																			Х	Х	Х
Activities not presented in this guide and emerging issues	1.38						Emissic	on sour	ces ma	ay vary o	deper	nding c	on the	e type o	of act	ivity or	issue	9.				

**Note 1:** The industrial sector corresponds to economic activities whose purpose is the transformation of materials into finished products or exploitation of the mineral wealth of the soil and energy sources. The mining sector is part of the primary sector of resource development (Government of Quebec, Thesaurus). Several emission sources are common to both sectors, which is why they have been grouped together.

Note 2: The decommissioning phase should be considered only when applicable.

Note 3: The "Water" sector covers all water-related activities. 3a) Identified sources apply to water retention activities only. 3b) The sources identified apply to activities carried out in aquatic and port environments.

Note 4: The processing of agricultural products is not part of animal production but rather of the agri-food industry. It is therefore necessary to refer to the emission sources associated with the "Industries" sector.

# APPENDIX B – ADDITIONAL INFORMATION ON HYDROCARBON EXPLORATION AND DEVELOPMENT PROJECTS





Source: adapted from WSP, October 2015. "Élaboration d'un projet type concernant les activités d'exploration et d'exploitation du pétrole et du gaz à Anticosti" (Sample project preparation regarding oil and gas exploration and development activities in Anticosti, French only).

# **APPENDIX C – GHG EMISSIONS MONITORING PLAN**

	Table 54. Examples of Data to be Included in a GHG Emissions Monitoring Plan (Non-Exhaustive)										
Category	Data type	Units	Data source	Frequency							
Motorized	Fuel consumption of each vehicle	Litres	Invoices	Monthly/annually							
Equipment	Mileage of each vehicle	Kilometres	Odometer	Monthly/annually							
	Hours of operation of off-road vehicles	Hours	Operations registry	Monthly/annually							
	Acquisition of new vehicles	Litres/100 kilometres	Invoices	Annually							
Buildings and	Natural gas consumption	Cubic metres	Invoices	Monthly							
Processes	Electricity consumption	Kilowatt-hours	Invoices	Monthly							
	Fuel oil consumption	Litres	Invoices	Monthly							
	Refrigerant refill	Kilograms	Invoices	Monthly							
	Consumption of carbonates	Tonnes	Invoices	Monthly							
	Consumption of carbon electrodes	Tonnes	Invoices	Monthly							
Waste Management	Percentage of emitted biogas captured at the technical landfill site (TLS)	Percentage	Measure	Monthly							
Projects	Quantity of biogas combusted at the TLS	Tonnes	Measure	Monthly							
	Quantity of recovered biogas	Tonnes	Measure	Monthly							
	Quantity of organic waste treated by composting	Tonnes	Measure	Monthly							
	Quantity of compost produced	Tonnes	Measure	Monthly							
	Quantity of waste incinerated	Tonnes	Measure	Monthly							
	Dry matter content of incinerated waste	Fraction	Measure	Monthly							

Table 54. Examples of Data to be Included in a GHG Emissions Monitoring Plan (Non-Exhaustive)									
Category	Data type	ata type Units							
	Composition of incinerated waste	Percentage	Operations registry	Monthly					
	Carbon fraction in incinerated waste	Fraction	Measure	Monthly					
	Fraction of fossil carbon in incinerated waste	Fraction	Measure	Monthly					
Livestock	Number of heads per animal type	Units	Operations registry	Monthly					
Production Projects	Quantity of manure stored	Tonnes	Measure	Monthly					
	Quantity of manure spread	Tonnes	Measure	Monthly					
	Quantity of synthetic fertilizer applied	Tonnes	Operations registry	Monthly					

## **APPENDIX D – COMPLEMENTARY INFORMATION ON BIOGENIC EMISSIONS**

According to the French agency for the environment and energy management (ADEME)<sup>99</sup>, there are two possible scenarios for biogenic CO<sub>2</sub> emitted by humans:

- Case 1: Either it is part of an overall change in ecosystems that does not contribute to increasing the atmospheric concentration of CO<sub>2</sub> because the increased emissions by humans are offset by a carbon sink (typical case of forest management); or
- Case 2: It is part of an emissions pattern not offset by carbon sinks (as in the case of deforestation or land-use change).

In general, in industrialized countries, where there is little deforestation, CO<sub>2</sub> emissions are offset by annual forest growth (case 1).

In addition:

- "Carbon-neutral" biogenic CO<sub>2</sub> emissions, even if not considered in GHG balances according to international conventions, nevertheless affect the climate and the quality of the atmosphere, which indiscriminately receives CO<sub>2</sub> of biogenic and non-biogenic origin.
- The IPCC, which is increasingly concerned with this issue and the carbon debt (see definition), recommends accounting for biogenic CO<sub>2</sub> emissions, particularly if a project is part of a pattern of emissions not offset by carbon sinks (case 2).
- In the Regulation respecting mandatory reporting of certain emissions of contaminants into the atmosphere (RMRCECA), a person or municipality operating a facility in Quebec must report its annual non-biogenic and biogenic GHG emissions separately.

#### Biogenic CO<sub>2</sub> emissions resulting from biomass combustion

CO<sub>2</sub> emissions from the combustion of biomass or biomass-derived products (biodiesel, construction, renovation and demolition wood, agricultural residues, etc.) are considered biogenic. However, CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass combustion are not considered biogenic and must be quantified with emissions from fossil fuel combustion.

<sup>99</sup> Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME), 2018. Base Carbone database (http://www.bilans-ges.ademe.fr/documentation/UPLOAD\_DOC\_FR/index.htm?co2\_biogenique.htm).

#### Biogenic CO2 emissions not resulting from biomass combustion

Waste disposal, composting, wastewater treatment, and other activities can produce CO<sub>2</sub> emissions due to biomass decomposition, and these emissions are considered biogenic. However, CH<sub>4</sub> and N<sub>2</sub>O emissions from this biomass decomposition are not biogenic and must be reported in their respective categories (waste, water treatment, etc.).

# **APPENDIX E – COMPLEMENTARY INFORMATION ON BLACK CARBON**

Airborne black carbon absorbs and scatters sunlight, increases temperatures, melts snow and ice, and impacts cloud formation and distribution. It can also influence air circulation and precipitation. The impact of black carbon is especially high in polar regions, such as the Arctic, where black carbon particles turn black as they settle on snow and ice, increasing their ability to absorb solar radiation and therefore accelerating the rate of melting.

Once emitted, black carbon remains in the atmosphere for a few days or weeks until it returns to the earth's surface as rain or by atmospheric deposition. Carbon dioxide, on the other hand, remains in the atmosphere for decades.

The Global warming potential (GWP) of black carbon varies according to the time period that is considered. Table 55 shows the GWP of black carbon over periods of 20, 100, and 500 years. The most frequently used period is 100 years. Over this period, the GWP of black carbon is estimated to be 900 times greater than that of CO<sub>2</sub>.<sup>100</sup>

Table 55. Global warming potential of black carbon over periods of 20, 100 and 500 years										
	GWP – 20 years	GWP – 100 years	GWP – 500 years							
Black Carbon	1 600	460	140							

Source: The International Council on Clean Transportation (ICCT) - A policy-relevant summary of black carbon climate science and appropriate emission control strategies. June 2009. <u>https://theicct.org/sites/default/files/BC\_policy-relevant\_summary\_Final.pdf</u>

It is important to note that these values are not officially published by IPCC. IPCC doesn't provide official GWP values for black carbon but has published data that allow researchers to derive these values. Reasons for not providing official GWP values include the short atmospheric lifetime of black carbon, complex climate interactions and ongoing research into its radiative forcing.

On November 28, 2017, Canada ratified the Gothenburg Protocol and its 2012 amendments under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Among the amendments to the Gothenburg Protocol are new commitments to reduce particulate matter emissions, with a priority focus on sources of particulate matter that are also significant sources of black carbon. At the 2017 Ministerial meeting of the Arctic Council, Canada, along with other Arctic states, renewed its commitment to take action to reduce black carbon emissions. At this meeting, Canada committed to continue to improve the quality and transparency of information on black carbon emissions and to publish an annual inventory of black carbon emissions. All emissions in this inventory are from anthropogenic (human) sources. Natural sources of black carbon, such as forest fires, are excluded.

<sup>&</sup>lt;sup>100</sup> Bond et al. 2013. Bounding the role of black carbon in the climate system – A scientific assessment. https://www.researchgate.net/publication/312193003\_Bounding\_the\_role\_of\_black\_carbon\_in\_the\_climate\_system\_-\_A\_scientific\_assessment.

#### The Gothenburg Protocol: an international consensus on black carbon<sup>101</sup>

The Gothenburg Protocol is an outcome of the Convention on Long-Range Transboundary Air Pollution. It was established to address pollutants that cause acidification of the biophysical environment and the formation of ground-level ozone, with the understanding that air pollutants cross borders and affect air quality far beyond their place of origin. This protocol sets limits for air pollutants, including sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds that are hazardous to health and the environment. It was updated in 2012 to include particulate matter and black carbon (a constituent of particulate matter) as well as new commitments for 2020.

#### Health impacts of black carbon

As for the health impacts of these particles, it is scientifically proven that they cause serious problems in the lungs and cardiovascular system. Because of their small size, black carbon and other fine particles can enter the lungs. People with pre-existing lung or heart disease, as well as the elderly and children, are particularly vulnerable to the effects of fine particles. Furthermore, there is no evidence of a safe level of exposure or a threshold below which no adverse health effects would occur. Furthermore, in June 2012, the World Health Organization (WHO) reclassified diesel exhaust emissions as a human carcinogen and the International Agency for Research on Cancer (IARC), part of the WHO, found sufficient evidence that exposure to diesel exhaust causes lung cancer (IARC, 2012).

The U.S. Environmental Protection Agency (EPA) estimated that the health benefits of reducing black carbon emissions were valued at \$230,000 to \$880,000 per ton of black carbon in 2010.

Finally, it is important to note that reducing carbon emissions is a "low-hanging fruit" because technological solutions are widely available and low-cost. Therefore, policy efforts to reduce black carbon will simultaneously reduce health risks and reduce anthropogenic impacts on the climate.

<sup>&</sup>lt;sup>101</sup> Environnement and Climate Change Canada. https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/gothenburg-protocol-air-pollution.html