Assessment of Sanitation GHG emissions and measures for Climate Change mitigation and adaptation in Senegal

The Global Green Growth Institute (GGGI)
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(Report translated from French)

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LIST OF COMMON ACRONYMS AND ABBREVIATIONS

FMECA BAU	Failure Mode, Effects and Criticality Analysis Business As Usual
UNFCCC	United Nations Framework Convention on Climate Change
CH4	Methane
CIVD	Integrated Waste Recovery Center
CO_2	Carbon dioxide
COMNACC	National Committee on Climate Change
INDC DA	Intended Nationally Determined Contributions Sanitation Directorate (MEA / Senegal)
DEEC	Directorate of Environment and Classified Establishments
EqCO2	Carbon Dioxide Equivalent (CO_2 Equivalent)
FSTP	Sludge Treatment Plant
GHG	Greenhouse gas
Gg	Gigagram
IPCC	Intergovernmental Panel on Climate Change
DRM	Disaster Risk Management
RCMP	Intergovernmental Panel on Climate
MEA	Ministry of Water and Sanitation (Senegal)
NDC	Nationally Determined Contribution
N_2O	Nitrogen protoxide or nitrous oxide
ONAS	National Sanitation Office
PNA RAC	National Adaptation Plan Joint Annual Review
SLM	Sustainable Land Management
WW	Wastewater
WWTP	Wastewater Treatment Plant

SUMMARY

As part of its climate change strategy, Senegal has almost always prioritized GHG inventories in its national communications, under the United Nations Framework Convention on Climate Change (UNFCCC). To meet its commitments, Senegal has already prepared and submitted three communications, the last of which was in 2015.

Considering the need to increase inventory frequency and accuracy, the GGGI sought to design a suitable methodology by adapting existing ones to take into account existing sanitation systems that consist predominantly of on-site facilities. This methodology is designed to provide a quality inventory of GHG emissions, especially from the wastewater sub-sector, along with an assessment of impacts on the climate, leading to the design of appropriate mitigation and adaptive measures to make sanitation services more resilient to the effects of climate change.

Key features this report is that it integrates GHG emissions and assesses population vulnerability and adaptations of the on-site system into the wastewater sub-sector's GHG emissions balance. This methodology should lead to an improved GHG emissions assessment model, in order to estimate the vulnerability of the systems to the effects of climate change.

This study highlights a considerable contribution of about 7.74% of the liquid sanitation sub-sector in the NDC. It also highlights the predominance of methane emissions with an inflection trend especially from 2025 onwards, based on the additional mitigation scenario.

Therefore, the mitigation measures require, not only a control of these emissions, but also methane recovery and a considerable reduction of untreated wastewater discharges into the environment.

Value chain-based adaptation focuses on latrines, septic tanks and cesspools whose emissions are very high due to the biological processes of prolonged fermentation taking place especially in rural areas. Therefore, the measures focus on the quality of the emptying equipment and, more importantly, on the recovery of methane as a source of energy at household level before collecting and transporting sludge for composting or discharge into the environment. In urban areas, the focus should be on energy recovery through incineration or the conversion of methane into electricity or equivalent clean energy.

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INTRODUCTION

1. Background

As part of its climate change strategy, Senegal has almost always prioritized GHG inventories in its national communications, under the United Nations Framework Convention on Climate Change (UNFCCC). To meet its commitments, Senegal has already prepared and submitted three communications, the last of which was in 2015.

The contribution from the waste sector, which includes solid and liquid waste, was assessed through a broad consultation process with stakeholders. According to the NDC, this sector contributes 11.21% of national emissions. The waste sector report indicates that liquid sanitation is responsible for only 1.01% of national emissions. Therefore, the GHG emission values are largely underestimated.

This NDC assessment does not sufficiently reflect sanitation conditions and services in Senegal context since 87.5% of the population is not connected to the sanitation network and uses on-site systems composed of septic tanks, latrines, etc. The management chain for sludge generated by these systems, from collection to recovery, transportation and treatment, has been ignored in the assessment of emission sources.

While the UNFCCC methodology and procedures are well understood, progress made in terms of accuracy since the first inventory was conducted remains limited. This is mainly due to the fact that the required data is not readily available; GHG inventories are carried out only occasionally and the required data is not collected on a regular basis. In addition, there is no framework or system for coordinating, collecting and centralizing data relevant to the preparation of GHG inventories in Senegal.

Considering the need to increase the frequency and accuracy of inventories, the GGGI sought to design a suitable methodology that takes into account existing sanitation systems that consist predominantly of on-site facilities. This methodology is designed to provide a quality inventory of GHG emissions, especially from the wastewater sub-sector, along with an assessment of impacts on the climate, leading to the design of appropriate mitigation and adaptive measures to make sanitation services more resilient to the effects of climate change.

What is unique about this method is that it integrates GHG emissions and assesses the population vulnerability and adaptations of the on-site system into the wastewater sub-sector's GHG emissions balance. This methodology should lead to an improved GHG emissions assessment model, in order to estimate the vulnerability of the systems to the effects of climate change, and produce an operational system for all sanitation services, covering both collective and on-site sanitation systems.

This study highlights a considerable contribution of about 7.74% of the liquid sanitation sub-sector in the NDC. It also highlights the predominance of methane emissions with an inflection trend from 2025 onwards, based on the additional mitigation scenario.

2. Objectives of the Study

The overall objective of the study is to design an appropriate methodology for existing sanitation systems dominated by on-site facilities, in order to conduct a quality inventory of the sub-sector's GHG emissions, along with an impact assessment in order to design adequate adaptation measures that will enhance the resilience of sanitation services to the effects of climate change.

The findings of the study will help better direct national planning and investments to achieve low-carbon growth; identify and guide actions to be taken to mitigate GHG emissions from the sector, specifically those that can benefit from the Sustainable Development Mechanism (SDM [1]); facilitate the implementation and application of regulatory instruments in favor of low-carbon activities and technologies; and finally, facilitate access to the UNFCCC and Paris Agreement financing mechanisms.

[1] The Agreement also provides for a mechanism, which all Parties may use, to "contribute to the mitigation of greenhouse gas emissions and promote sustainable development. This mechanism, which calls on "public and private entities authorized by a Party" to "contribute to global $_{CO2}$ mitigation", will be overseen by the UNFCCC.

CHAPTER I: METHODOLOGY

1. Methodology

1.1. Literature Review

The data will essentially come from strategic planning documents and also from the evaluation of previous programs on access, completed projects and infrastructures that could generate GHGs.

- Annual ONAS operating reports,
- The PEPAM evaluation report,
- The SDG project documents,
- Reports and publications of the Intergovernmental Panel on Climate Change (IPCC),
- United Nations Framework Convention on Climate Change (UNFCCC) guidelines,
- The NDC (nationally determined contribution),
- The December 2015 COP 21 reports,
- Ministry of Water and Sanitation Sector Development Policy Letter (LPSD 2016-2025),
- National Urban Sanitation Strategy (SNAU),
- Methodologies recognized by the IPCC and the UNFCCC for assessing GHG emissions and systems' vulnerability to the effects of climate change,
- Etc.

1.2. Interviews with the Relevant Departments

The key players identified a priori are as follows:

- MEA \ DA
- ONAS
- DEEC
- GGGI

Visits to and interviews with stakeholders will be conducted and meeting or interview memos will be prepared in order to better guide the sector's vision regarding the management of existing sanitation systems.

1.3. GHG Inventory System

A national inventory is a quantified estimate of greenhouse gas emissions generated within a country's territory by sources and their absorption by carbon sinks. This inventory must be structured in accordance with IPCC guidelines to meet the reporting requirements of the UNFCCC and comply with an internationally accepted inventory model that aggregates emissions from the following six sectors: Energy, Industrial Processes, Solvents and Other Products, Agriculture and Livestock, Land Use Change and Forestry, and Waste.

This technical proposal to assess the contribution of the sanitation sector to GHG emissions and identify sector-specific climate change mitigation and adaptation measures applies to the liquid waste subsector.

1.3.1. GHG Emission Sources

The main sources of greenhouse gases for collective sanitation are wastewater ventilations in plants and network pumping. For non-collective sanitation, the transportation of sludge by truck and the sludge treatment process can be a major source of emissions.

The main GHGs emitted are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Table 1: GHG Production Sources

Gas	Production
CO_2	– During sludge transport (emptying trucks) in the case of non-collective sanitation - During wastewater treatment, mainly due to organic matter degradation; - Linked to the production of electricity to supply the plant - During sludge treatment: combustion or flaring of biogas, on-site sludge incineration - Direct discharges into water courses without treatment
CH_4	- Networked sewage: emissions in the case of stagnant, open and hot sewers - At the WWTP: production by decomposition of organic matter under anaerobic conditions (COD treatment) - Potential CH_4 leakage during biogas production - Emissions when discharging to sea, river or lake
N_2O	- On the WWTP, linked to the treatment of nitrogen present in wastewater - Urea, ammonium, proteins (NTK reduction). - During the discharge of treated water into the natural environment, during composting or sludge spreading - During sludge incineration. It should be noted that N_2O emission occurs naturally in natural aquatic environments (rivers, estuaries, lakes)

1.3.2. IPCC Guidelines for Inventory Preparation

The Intergovernmental Panel on Climate Change (IPCC) has published guidelines for national greenhouse gas emission inventories. With respect to inventories, we shall refer to the following:

- Chapters 5 and 6, of Volume 5 and Chapter 11, Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, on incineration, wastewater treatment and discharges, and N_2O emissions from managed soils respectively.
- Chapters 2 and 3 of Volume 2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories on stationary combustion (generators for electricity production) and mobile combustion (for transportation) respectively.

2. Inventory of GHG Emissions from the Sanitation Sub-Sector

2.1. Global Warming Potential of GHG Emissions

Sanitation services consume energy both for wastewater transportation (in particular at collection stations and for emptying trucks) and for the treatment operation itself. Besides, considering the need to increase the treatment level to avoid degrading the receiving environment, this energy requirement could be increased.

Further, wastewater, both domestic and industrial, contains a significant amount of organic matter that cause (especially during treatment) to methane (CH_4) and nitrous oxide (N_2O), emissions which are gases with more greenhouse effect than carbon.

The GWP values used are those established by the Intergovernmental Panel on Climate Change (IPCC), in accordance with Decision 17/CP.8 of the UNFCCC, for the preparation of national emission inventories.

Greenhouse gases have different impacts on the climate. To help compare the impacts of these gases on the climate, the IPCC, through its reports, provides a characterization factor for them known as the Global Warming Potential (GWP). The GWP is established over a characteristic period of 20, 50, 100 or 500 years. The emission of 1g of a greenhouse with a GWP of X is equivalent to the emission of X g of CO_2. This is referred to as a **kilogram of CO_2 equivalent (kgCO_2e)**.

The GWPs of the various gases change over the course of the reports for technical reasons related to climate change modeling and for physical reasons related to the correlation between the GWP and the concentration of GHGs already released into the atmosphere.

The Carbon Base values are calculated using the **100-year GWPs of the 5th IPCC report** (the latest). Consult the IPCC website: http://www.ipcc.ch/report/ar5/wg1/.

Table 2: Comparative 100-Year Global Warming Potential (GWP) of CO_2, CH_4 and N_2O (on a mass basis)

Name of the gas	100-year GWP	
	4th IPCC report	5th IPCC report
CO_{2f}	1	1
CH_{4f}	25	30
CH_{4b}	25	28
N_2O	298	265
SF_6	22800	26100
CO_{2b}	-	-

Calculating CO_2b (CO_2 of biogenic origin) quantities requires special consideration. The available mainstream literature provides details about how it is calculated. In the Carbon Base ®, CO_2b is always counted separately and is not reported in the totals.

2.2. Emission Potential of CH_4, N2O and CO_2b

The main factor that determines the production potential of methane in wastewater is the amount of organic matter in effluents. For domestic wastewater, commercial wastewater and sludge, this amount is expressed as Biochemical Oxygen Demand (BOD); for industrial wastewater, Chemical Oxygen Demand (COD) is used. The BOD indicates the amount of carbon that is aerobically biodegradable, while the COD indicates the total amount of biodegradable and non-biodegradable carbon available for oxidation. This is a change from the previous methodology (IPCC, 1995) which used the BOD as an organic matter parameter for both domestic/commercial and industrial effluents. An important addition to the previous methodology is the inclusion of sludge-generated emissions. Sludge, which is produced as a by-product of some wastewater treatment systems, can produce methane under anaerobic conditions.

In addition to the emission factors listed in the following table, GHGs from the following sources also need to be taken into account:

- Direct and indirect emissions related to consumables, transportation and infrastructure;
- Open defecation-related emissions;
- Emissions related to the burning or processing of solid waste.

Emissions avoided during the treatment and recovery of sludge in the form of biogas-generated electrical or thermal energy production from, in the form of fertilizers or in the form of substitute fuels or as a mineral in cement works.

Table 3: GHG Emission Potential for Wastewater and Sludge Treatment and Discharge Systems

(source: IPCC, 2006)

Legend: No emissions | Risk of emissions | Emissions

Type of treatment and discharge					CH_4, N_2O and CO_2 emission potential	CH_4	N2O	CO2
Collected wastewater	Untreated	Discharge into water courses and water bodies			Stagnant, oxygen-poor rivers and lakes can facilitate anaerobic decomposition to produce CH_4. Rivers, lakes and estuaries are possible sources of N_2O.	Risk of emissions	Risk of emissions	No emissions
		Sewers (closed and underground)			Are not a source of CH_4/N_2O.	No emissions	No emissions	No emissions
		Sewers (open air)			Open-air sewers and stagnant, saturated ditches/channels are significant sources of CH_4	Risk of emissions	No emissions	No emissions
	Treated	Aerobic treatment	Aerobic wastewater treatment plants	Well-designed and well-managed	Can produce a limited volume of CH_4 from anaerobic pockets. Sophisticated plants with nutrient removal capability (nitrification and denitrification) are minor but specific sources of N_2O	Risk of emissions	No emissions	No emissions
				Poorly designed and managed	Production of CH_4	Emissions	Risk of emissions	No emissions
			Anaerobic sludge treatment in centralized aerobic wastewater treatment plants	With CH_4 recovery or burning	CH_4 emitted by the sludge is recovered or flared	No emissions	No emissions	No emissions
				Without CH_4 recovery or burning	Sludge can be a significant source of CH_4 if the CH_4 emitted is not recovered or flared.	Emissions	No emissions	No emissions
			Temporary surface water bodies under aerobic conditions	Well-designed and well-managed	Improbable source of CH_4/N_2O	No emissions	No emissions	No emissions
				Poorly designed and managed	CH_4 production	Emissions	No emissions	No emissions
		Anaerobic treatment	Anaerobic lagoons		Possible source of CH_4 Not a source of N_2O	Risk of emissions	No emissions	No emissions
			Anaerobic reactors	With CH_4 recovery or burning	CH_4 emitted by anaerobic reactors is recovered or flared	No emissions	No emissions	No emissions
				Without CH_4 recovery or burning	Can be a significant source of CH_4 if the CH_4 emitted is not recovered or flared	Emissions	No emissions	No emissions
Uncollected wastewater	Septic tanks		With frequent evacuation of solid materials		Low CH_4 production	Risk of emissions	No emissions	No emissions
			Without frequent evacuation of solid materials		CH_4 production	Emissions	No emissions	No emissions
	Open pits / Latrines				Pits/latrines can produce CH_4 if temperature and retention time are favorable	Risk of emissions	No emissions	No emissions
	Discharge into waterways (Discharge into waterways and water bodies)				See above	Risk of emissions	Risk of emissions	No emissions

3. Reference and Mitigation Scenarios for GHG Emissions

3.1. Reference Scenario

The reference case emissions are used as a baseline to define the goals of a reference scenario (Figure 1). A reference scenario hypothetically illustrates what future events or conditions would be like if no measures are put in place to achieve mitigation goals. The reference scenario is also known as the business-as-usual (BAU) scenario. It refers to any type of emissions projection and is often used to describe a type of scenario in which policies are already adopted and implemented. The definition of a reference scenario may hinge on a wide variety of data, such as data on the underlying drivers of emissions (economic activity, energy prices, population growth, etc.), assumptions about how emission vectors are likely to change during the implementation period, and data on the impacts of implemented and adopted actions and policies. Baseline scenario emissions are an estimate of GHG emissions associated with a baseline scenario.

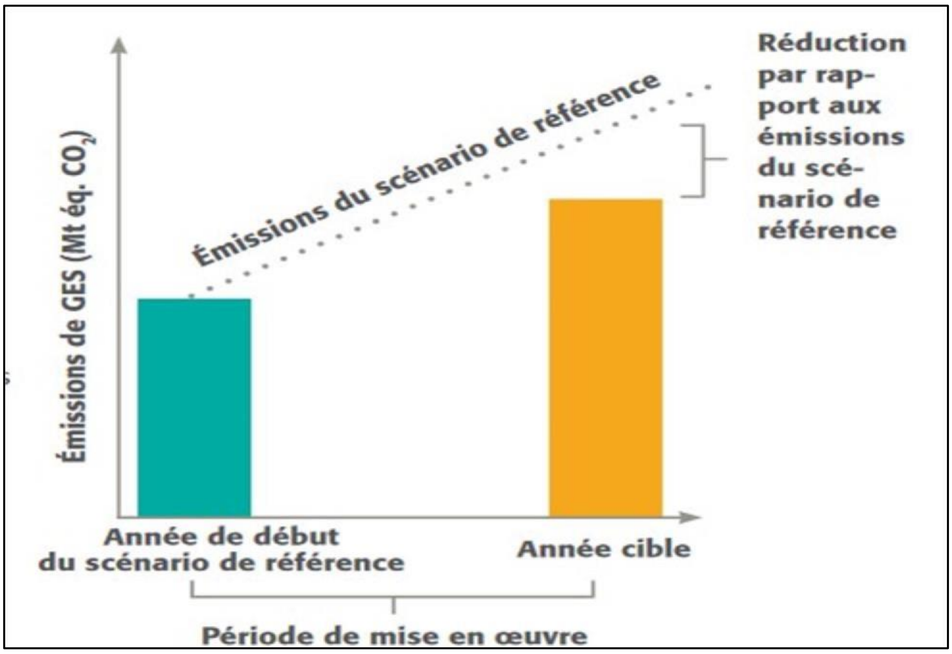

Figure 1: Baseline Scenario Emissions

The baseline and mitigation scenario projections cover the period between 2015 and 2030. Emission values are reported with a time step of 5 years.

3.2. Mitigation Scenarios

Mitigation scenarios may be classified into two categories:

- The unconditional mitigation scenario is based on the implementation of projects whose funding and implementation are fully controlled by the government, while ;
- The conditional mitigation scenario hypothesizes the implementation of additional projects with external funding over the 2015-2030 period.

3.3. Status of Sanitation Sub-sector Projects

The urban sanitation portfolio includes 38 projects totaling CFA F 239.4 billion, of which 18.8 billion were disbursed over the 2016-2017 period (RAC, 2018). Therefore, the access rate in urban areas was 67.4% in 2017 compared to 66.5% in 2016, which represents a slight increase compared to the previous year and to the 2016 target (67%). Achieving the objectives of the urban sanitation sub-sector requires accelerating the supply of new improved sanitation systems and connections to the sewer system to meet the high demand from households, and addressing the slow pace of non-objection notices for projects financed by partners. With respect to rural sanitation, the access rate to improved sanitation facilities by people in rural areas stood at 42.3% in 2017 compared to 38.7% in 2016, which represents a 3.6-point increase. Rural sanitation outcomes have shown a positive trend thanks to efforts in the construction of latrines and public aediculae. For example, 2393 latrines and 27 public aediculae were built in 2017. In addition, the wastewater treatment rate was 55.6% in 2017 compared to 55.4% in 2016. Similarly, the wastewater treatment rate increased from 34.8% in 2016 to 35.1% in 2017. As part of efforts to address flooding, 17 pumping stations were built, 46 pumping stations were rehabilitated/reinforced and 37 km of drainage systems were built.

4. Inventory Methodology for Wastewater Treatment and Discharge

When treated or disposed of anaerobically, wastewater can be a source of methane (CH_4), just as it can be a source of nitrous oxide (N_2O) emissions. Wastewater comes from many domestic, commercial and industrial sources. It may be treated on site (uncollected), piped through sewers to a treatment plant (collected), or discharged untreated nearby or through an overflow.

Sewers can be closed or open. In the urban areas of some developed and developing countries, sewer systems may consist of networks of open channels, gutters and ditches that are commonly referred to as open sewers. In many developed countries, and in the wealthier urban areas of other countries, sewers are generally closed and buried. Wastewater in closed and buried sewers appears not to be a major source of CH_4 emissions. However, this is not the case for wastewater passing through open sewers because it is subject to heating by the sun and when it stagnates in the sewer it can enhance anaerobic conditions and produce CH4 (Doorn et al., 1997). Figure 2 shows different approaches to wastewater treatment and discharge.

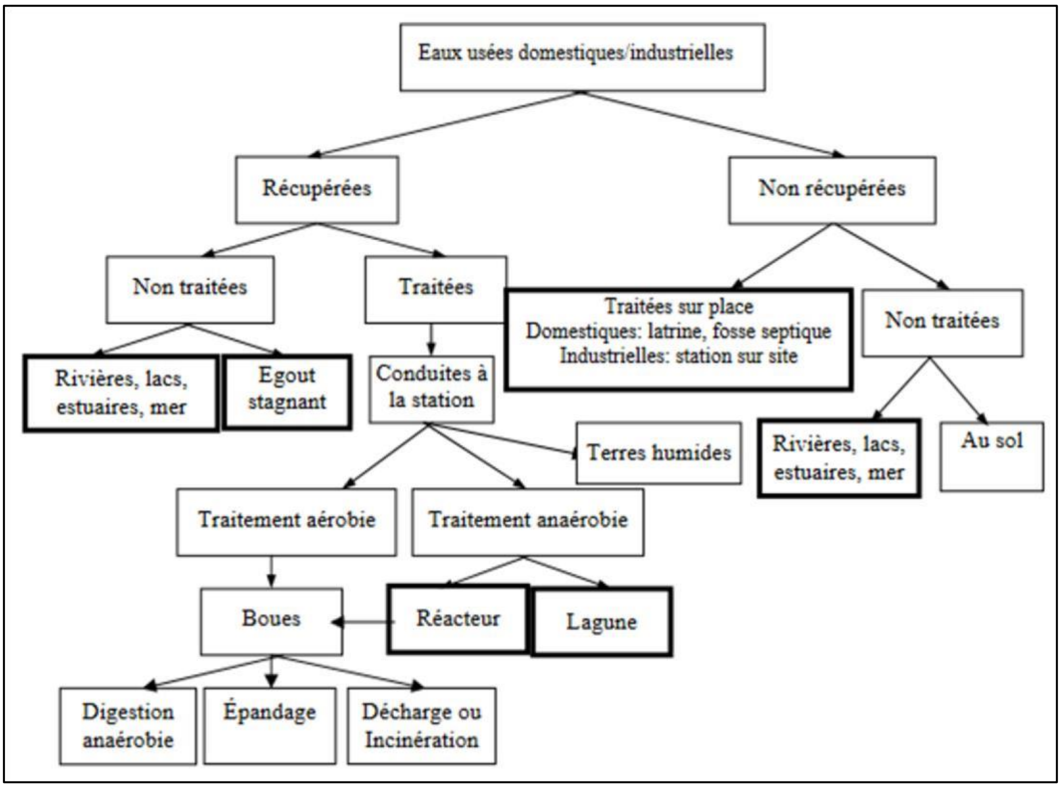

Figure 2: Wastewater treatment system and disposal routes

Methane (CH_4)

Wastewater and its sludge components can produce CH_4 if anaerobically degraded. The amount of CH_4 produced depends primarily on the amount of biodegradable material in the wastewater, temperature and the treatment system. The rate of CH_4 production increases with rising temperatures. This is especially significant in unregulated systems and in hot climates.

Nitrous Oxide (N_2O)

Nitrous oxide (N_2O) is associated with the degradation of nitrogen compounds in wastewater (e.g., urea, nitrate and protein). Domestic wastewater includes human discharges mixed with other domestic wastewater, and may include effluent from shower installations, sinks, washing machines, etc. Centralized wastewater treatment systems can include a variety of processes ranging from lagooning to advanced tertiary treatment technologies used for the removal of nitrogen compounds.

Treatment and Discharge Systems and CH_4 and N_2O Production Potential

Treatment systems or discharge channels that feed anaerobic environments typically produce CH_4 while systems that feed aerobic environments typically produce little or no CH_4 at all. For example, lagoons with no mixing or aeration have a depth that is critical to CH_4 production. Shallow lagoons with a depth of less than 1 meter provide aerobic conditions with insignificant or no CH_4 production. Lagoons deeper than 2-3 meters support anaerobic environments and substantial CH_4 production.

4.1. Wastewater Methane Emissions

Emissions vary according to the volume of organic waste produced and an emission factor explaining the degree to which the waste produces CH_4. Three-tier methods for CH_4 in this category are explained here: The Tier 1 method applies default values for the emission factor and activity parameters. This method is considered good practice for countries with limited data. The Tier 2 method follows the Tier 1 method but allows for the incorporation of a country-specific emission factor and activity data. For example, a specific emission factor for a large wastewater treatment system can be incorporated based on field data. The volume of sludge removed for incineration, landfill and agricultural land should be taken into account.

In countries with good data and advanced methodologies, a country-specific method could be applied as a Tier 3 method. An even more advanced country method could be developed based on data from large wastewater treatment plants. Figure 3 below shows a decision tree for domestic wastewater

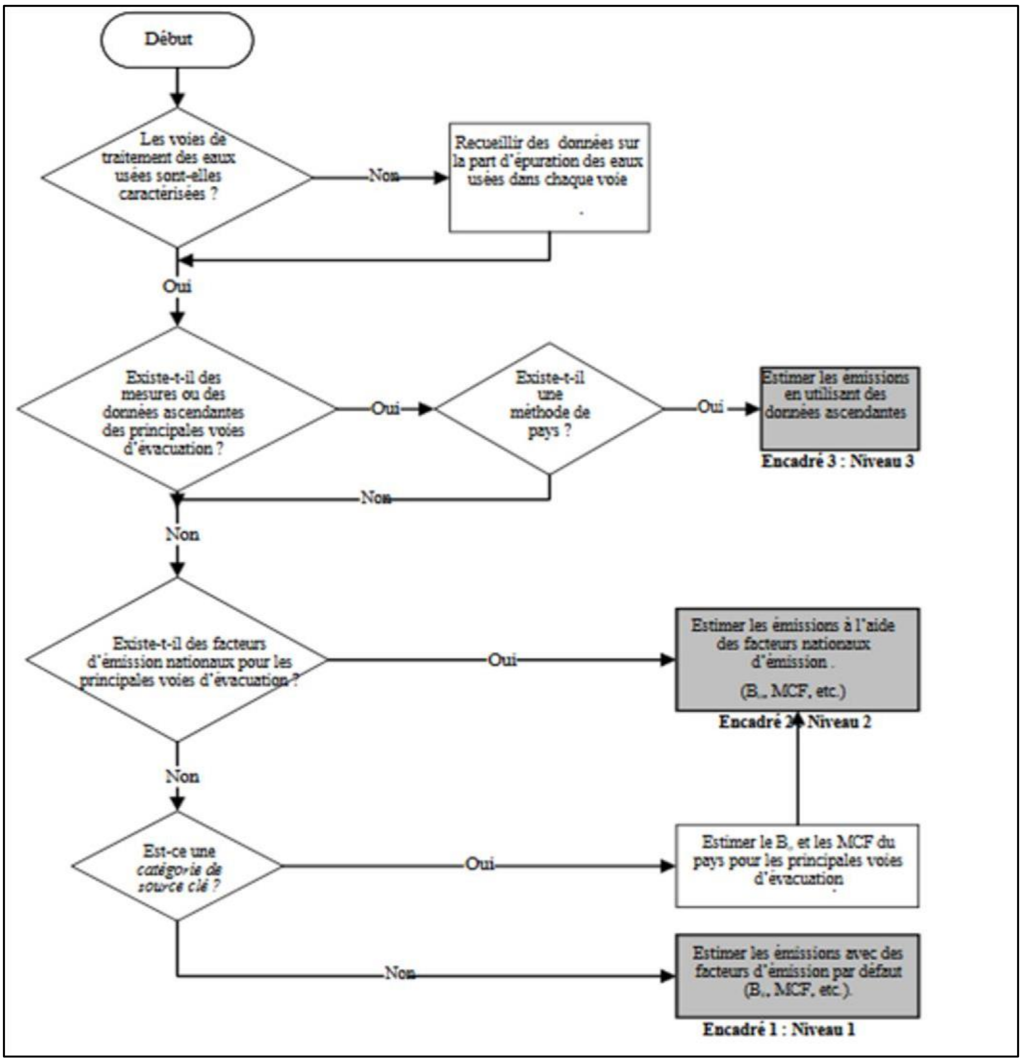

Figure 3: Decision tree for CH_4 emissions from domestic wastewater

The following steps are recommended in good inventory preparation practices for CH_4 in domestic wastewater:

- Step 1: Use Equation 6.3 to estimate total biodegradable carbon in wastewater (TOW);
- Step 2: Select routes and systems based on country activity data. Use Equation 6.2 to calculate the emission factor for each domestic wastewater treatment or discharge process or system;
- Step 3: Use Equation 6.1 to estimate emissions, make adjustments for sludge removal and/or CH4 recovery, and then aggregate the results for each process or system.

Wastewater characterization will determine the fraction of wastewater treated or discharged by a given system. To determine how much of each type of treatment or discharge system is used, good practice recommends using national statistics (e.g., from regulatory authorities). If such data are not available, associations of wastewater treatment facilities or international organizations such as the World Health Organization (WHO) may have data on which system is used. Alternatively, sanitation experts could be consulted or expert judgments applied.

Further, there may be differences between high- and low-income residents in developing countries. For this reason, a U-factor has been introduced to express each fraction by income class. Good practice recommends treating the following three categories separately: rural population, high-income urban population and low-income urban population. A spreadsheet could be used for this purpose, as suggested in Table 6.5 below. The general equation for estimating CH_4 emissions from domestic wastewater is as follows:

ÉQUATION 6.1
EMISSIONS TOTALES DE CH_4 PROVENANT DES EAUX USEES DOMESTIQUES

$$Emissions\ CH_4 = \left[\sum_{i,j} \left(U_i \bullet T_{i,j} \bullet EF_j\right)\right]\left(TOW - S\right) - R$$

Where:

CH_4 emissions = CH_4 emissions in the inventory year, kg CH_4/year
TOW = total organic matter in wastewater in the inventory year, kg BOD/year S = organic component removed as sludge in the inventory year, kg BOD/year
Ui= population fraction by i-income group in the inventory year (see Table 6.5.)
Ti,j= degree to which the treatment and/or disposal route or system, j, is used for each i-income group fraction in the inventory year (see Table 6.5.)
i = income category: rural, high-income urban and low-income urban, j = each treatment and/or disposal route or system
EFj= emission factor, kg of CH_4 / kg BOD
R = volume of CH4 recovered in the inventory year, kg CH_4/year

4.1.1. *Selection of Emission Factors*

The emission factor for a wastewater treatment and/or disposal system or route depends on the maximum CH_4 generation potential (Bo) and the methane correction factor (MCF) of the wastewater treatment and disposal system, as shown in Equation 6.2. Bo is the maximum amount of CH_4 that can be produced by a given amount of organic matter (expressed as BOD or COD) contained in the wastewater. The MCF shows how much of the CH_4 production capacity (Bo) is achieved in each type of treatment system and disposal route. In other words, the MCF indicates the extent to which the system is anaerobic.

ÉQUATION 6.2
FACTEUR D'EMISSION DE CH_4
POUR LA VOIE OU SYSTEME DE TRAITEMENT ET/OU D'ELIMINATION DES EAUX USEES DOMESTIQUES

$$EF_j = B_o \bullet MCF_j$$

Where:

EFj = emission factor, kg CH4/kg BOD
j = each treatment and/or disposal route or system Bo
= maximum CH4 production capacity, kg CH4/kg
BOD MCFj = methane correction factor (fraction), see
Table 6.3.

Good practice recommends using country data for Bo, if available, expressed in terms of kg CH_4/kg BOD removed so that these data are consistent with activity data. In the absence of country data, a default value (0.6 kg CH_4/kg BOD) can be used. For domestic wastewater, a COD-based Bo value may be converted to a BOD-based value by multiplying it by a factor of 2.4. Table 6.2 contains a default maximum production capacity (Bo) of CH_4 for domestic wastewater.

Table 4: Default Maximum CH_4 Production Capacity (Bo) for Wastewater

0.6 kg CH_4/kg BOD
0.25kgCH_4/kg COD
Based on expert judgment by the authors and Doom et al, (1997)

Table 5: Default MCF Values for Domestic Wastewater

Type de traitement et voie ou système d'élimination	Observations	MCF [1]	Gamme
Système non traité			
Rejet en mer, rivière ou dans un lac	Les rivières à forte charge organique peuvent devenir anaérobies.	0,1	0 – 0,2
Égout stagnant	Ouvert et chaud	0,5	0,4 – 0,8
Égout en écoulement (ouvert ou fermé)	Rapide, propre (volumes insignifiants de CH_4 des stations de pompage, etc.)	0	0
Système traité			
Installation centrale de traitement aérobie	Doit être bien gérée. Une certaine quantité de CH_4 peut être libérée des décanteurs ou d'autres poches.	0	0 – 0,1
Installation centrale de traitement aérobie	Mal gérée ; saturée	0,3	0,2 – 0,4
Méthaniseur de boues	La récupération du CH_4 n'est pas envisagée ici.	0,8	0,8 – 1,0
Réacteur anaérobie	La récupération du CH_4 n'est pas envisagée ici.	0,8	0,8 – 1,0
Étang d'épuration peu profond et anaérobie	Profondeur de moins de 2 mètres ; recourir au jugement d'expert.	0,2	0 – 0,3
Étang d'épuration profond avec conditions anaérobies	Profondeur de plus de 2 mètres	0,8	0,8 – 1,0
Système septique	La moitié de la BOD s'installe dans le réservoir anaérobie.	0,5	0,5
Latrine	Climat sec, nappe phréatique plus profonde que la latrine, famille réduite (3-5 personnes)	0,1	0,05 – 0,15
Latrine	Climat sec, nappe phréatique plus profonde que la latrine, collective (nombreux utilisateurs)	0,5	0,4 – 0,6
Latrine	Climat humide/eau d'entraînement, nappe phréatique moins profonde que la latrine	0,7	0,7 – 1,0
Latrine	Enlèvement régulier de sédiment pour engrais	0,1	0,1

[1] Basé sur le jugement d'expert par les auteurs principaux de cette section.

4.1.2. Selection of Activity Data

The activity data for this source category is the overall volume of biodegradable material contained in the wastewater (TOW). This parameter is determined according to human population and BOD production per capita. It is expressed in terms of biochemical oxygen demand (kg BOD/year). The equation for TOW is as follows:

ÉQUATION 6.3
TOTAL DE MATIERES BIODEGRADABLES DANS LES EAUX USEES DOMESTIQUES

$$TOW = P \bullet BOD \bullet 0{,}001 \bullet I \bullet 365$$

Where:

TOW = total wastewater organic matter in the inventory year, kg BOD/year P = national population in the inventory year, (person)
BOD = BOD per capita per country in the inventory year, g/person/day, see Table 8. 0.001 = conversion from grams BOD to kg BOD
I = correction factor for any additional industrial BOD discharged to sewers (for collected wastewater the default value is 1.25; for uncollected wastewater it is 1.00).

The values for Factor I in Equation 6.3 are based on expert judgment by the authors or expert judgment where statistics or other comparable data are not available. The table includes default values for Ui and Ti,j for a range of countries.

Table 6: Estimated BOD5 Values of Domestic Wastewater for Some Regions and Countries

Pays/Région	BOD_5 (g/personne/jour)	Gamme	Référence
Afrique	37	35 – 45	1
Egypte	34	27 – 41	1
Asie, Moyen Orient, Amérique latine	40	35 – 45	1
Inde	34	27 – 41	1
Cisjordanie et Bande de Gaza (Palestine)	50	32 – 68	1
Japon	42	40 – 45	1
Brésil	50	45 – 55	2
Canada, Europe, Russie, Océanie	60	50 – 70	1
Danemark	62	55 – 68	1
Allemagne	62	55 – 68	1
Grèce	57	55 – 60	1
Italie	60	49 – 60	3
Suède	75	68 – 82	1
Turquie	38	27 – 50	1
États-Unis	85	50 – 120	4

Note: Ces valeurs se basent sur une évaluation de la littérature. Veuillez utiliser les valeurs nationales si elles existent.

Référence:

1. Doorn & Liles (1999).
2. Feachem *et al.* (1983).
3. Masotti (1996).
4. Metcalf & Eddy (2003).

Table 7: Default Values for Urbanization (U) and Degree to Which the Treatment Method or Disposal Route is Used (Ti,j) for Each Income Category in Selected Countries

	Urbanisation(U) [1] Fraction de population			Degré d'utilisation de la méthode de traitement ou de voie d'évacuation pour chaque classe de revenu ($T_{i,j}$) [3] — U=pop. rurales					U= pop. urbaine à revenus élevés					U=pop. urbaine à bas revenus				
Pays	Rural	urb-élevé[2]	urb-bas[2]	Fosse septi-que	Latrine	Autre	Egout[4]	Aucun	Fosse septi-que	Latrine	Autre	Egout[4]	Aucun	Fosse septi-que	Latrine	Autre	Egout[4]	Aucun
Afrique																		
Nigeria	0,52	0,10	0,38	0,02	0,28	0,04	0,10	0,56	0,32	0,31	0,00	0,37	0,00	0,17	0,24	0,05	0,34	0,20
Egypte	0,57	0,09	0,34	0,02	0,28	0,04	0,10	0,56	0,15	0,05	0,10	0,70	0,00	0,17	0,24	0,05	0,34	0,20
Kenya	0,62	0,08	0,30	0,02	0,28	0,04	0,10	0,56	0,32	0,31	0,00	0,37	0,00	0,17	0,24	0,05	0,34	0,20
Afrique du Sud	0,39	0,12	0,49	0,10	0,28	0,04	0,10	0,48	0,15	0,15	0,00	0,70	0,00	0,17	0,24	0,05	0,34	0,20
Asie																		
Chine	0,59	0,12	0,29	0,00	0,47	0,50	0,00	0,3	0,18	0,08	0,07	0,67	0,00	0,14	0,10	0,03	0,68	0,05
Inde	0,71	0,06	0,23	0,00	0,47	0,10	0,10	0,33	0,18	0,08	0,07	0,67	0,00	0,14	0,10	0,03	0,53	0,20
Indonésie	0,54	0,12	0,34	0,00	0,47	0,00	0,10	0,43	0,18	0,08	0,00	0,74	0,00	0,14	0,10	0,03	0,53	0,20
Pakistan	0,65	0,07	0,28	0,00	0,47	0,00	0,10	0,43	0,18	0,08	0,00	0,74	0,00	0,14	0,10	0,03	0,53	0,20
Bangladesh	0,72	0,06	0,22	0,00	0,47	0,00	0,10	0,43	0,18	0,08	0,00	0,74	0,00	0,14	0,10	0,03	0,53	0,20
Japon	0,20	0,80	0,00	0,20	0,00	0,50	0,30	0,00	0,00	0,00	0,10	0,90	0,00	0,10	0	0	0,90	0
Europe																		
Russie	0,37	0,73	0,00	0,30	0,10	0,00	0,60	0,00	0,10	0,00	0,00	0,90	0,00	Néant	Néant	Néant	Néant	Néant
Allemagne[5]	0,06	0,94	0,00	0,20	0,00	0,00	0,80	0,00	0,05	0,00	0,00	0,95	0,00	Néant	Néant	Néant	Néant	Néant
Royaume-Uni	0,10	0,90	0,00	0,11	0,00	0,00	0,89	0,00	0,00	0,00	0,00	1,00	0,00	Néant	Néant	Néant	Néant	Néant
France	0,24	0,76	0,00	0,37	0,00	0,00	0,63	0,00	0,00	0,00	0,00	1,00	0,00	Néant	Néant	Néant	Néant	Néant
Italie	0,32	0,68	0,00	0,42	0,00	0,00	0,58	0,00	0,04	0,00	0,00	0,96	0,00	Néant	Néant	Néant	Néant	Néant
Amérique du Nord																		
Etats-Unis	0,22	0,78	0,00	0,90	0,02	0,00	0,08	0,00	0,05	0,00	0,00	0,95	0,00	Néant	Néant	Néant	Néant	Néant
Canada	0,20	0,80	0,00	0,90	0,02	0,00	0,08	0,00	0,05	0,00	0,00	0,95	0,00	Néant	Néant	Néant	Néant	Néant
Amérique latine et Caraïbes																		
Brésil	0,16	0,25	0,59	0,00	0,45	0,00	0,10	0,45	0,00	0,20	0,00	0,80	0,00	0,00	0,40	0,00	0,40	0,20
Mexique	0,25	0,19	0,56	0,00	0,45	0,00	0,10	0,45	0,00	0,20	0,00	0,80	0,00	0,00	0,40	0,00	0,40	0,20
Océanie																		
Australie et Nlle-Zélande	0,08	0,92	0,00	0,90	0,02	0,00	0,08	0,00	0,05	0,00	0,00	0,95	0,00	Néant	Néant	Néant	Néant	Néant

Notes:
(1.) Projections d'urbanisation pour 2005 (Nations Unies, 2002). (2.) Division proposée en classes urbaines à revenus élevés et faibles. Les pays sont encouragés à utiliser leurs données propres ou le meilleur jugement. (3.) Les valeurs T_{ij} sont basées sur un jugement d'expert. (Doorn & Liles, 1999). (4.) Selon que les égouts sont ouverts ou fermés, cela déterminera le choix de MCF (cf Tableau 3.3) (5.) Destatis, 2001
Note: Ces valeurs sont tirées de la littérature ou basées sur un jugement d'expert. Utiliser des valeurs nationales si elles existent.

The following table provides an example. Categories with insignificant contribution are not included. A column for MCF can be added to the table for each category. The urbanization index for this country is set at 65%.

Table 8: Example of the Application of Default Values for Treatment Use Levels (T) by Income Category

Système ou de traitement ou voie d'évacuation		T (%)	Notes
Populations urbaines à revenus élevés	À la mer	10	Pas de CH_4
	À une station aérobie	20	Ajouter composant industriel
	À des fosses septiques	10	Déchets non ramassés
Populations urbaines à bas revenus	À la mer	10	Déchets ramassés
	À des latrines	15	Déchets non ramassés
Populations rurales	Aux rivières, lacs, mer	15	Déchets non ramassés
	à des latrines	15	
	À des fosses septiques	5	
Total		100%	Doit être de 100 %
Référence: Doorn & Liles (1999)			

Emission Factors

Where domestic wastewater is concerned, inventory compilers can compare national Bo values to the IPCC default value (0.25 kg CH_4/kg COD or 0.6 kg CH_4/kg BOD). Although there are no IPCC default values, for the fraction of anaerobically treated wastewater, inventory compilers are encouraged to compare the MCF values to those of countries that treat wastewater in a similar manner.

Inventory compilers should confirm agreement between the units used for degradable carbon in waste (TOW) and Bo. Both parameters must be based on the same units (BOD or COD) in order to calculate emissions. This must be taken into account when comparing emissions.

4.2. Nitrous Oxide Emissions from Wastewater and Methodological Considerations

Emissions of nitrous oxide (N_2O) can occur directly from wastewater treatment plants or indirectly from wastewater after effluent discharge into rivers, lakes or the sea. Direct emissions caused by nitrification and denitrification at wastewater facilities can be considered as a minor source. Guidance on how to estimate these emissions is provided in Box 6.1. The simplified general equation is as follows:

ÉQUATION 6.7

EMISSIONS DE N_2O ISSUES DE L'EFFLUENT D'EAUX USEES

$$Emissions\ N_2O = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44/28$$

Where:

N2O Emissions = N_2O emissions in the inventory year, N_2O kg/yr.
N EFFLUENT = Nitrogen in effluent that is discharged into aquatic environments, N kg/yr
EF EFLUENT = Emission factor for N_2O emissions from wastewater discharges, N_2O- N kg/kg N The 44/28 factor is the conversion of N_2O-N kg to N_2O kg.

The IPCC default emission factor for N_2O emissions from domestic wastewater nitrogen effluent is 0.005 (0.0005 - 0.25) kg N_2O-N/kg N. This factor is based on limited operational data and specific assumptions regarding the occurrence of nitrification and denitrification processes in rivers and estuaries. The first assumption is that all nitrogen is released with the effluent. The second assumption is that N_2O production in rivers and estuaries is directly related to nitrification and denitrification and therefore to the nitrogen released to the river.

$$N_{EFFLUENT} = (P \bullet Protéine \bullet F_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{BOUES}$$

ÉQUATION 6.8
TOTAL D'AZOTE DANS L'EFFLUENT

Where:

N EFFLUENT = total annual volume of nitrogen in wastewater effluent, kg N/yr P = human population Protein = annual per capita protein consumption, kg/person/year FNPR = fraction of nitrogen in protein, default = 0.16, kg N/kg protein FNON-CON = factor for unconsumed protein added to wastewater.

FIND-COM = factor for industrial and commercial protein co-discharged to the sewer system NSLUDGE = nitrogen removed from sludge (default = zero), kg N/yr.

Subcategory: Emissions from Centralized Wastewater Treatment Facilities

Emissions from centralized and advanced wastewater treatment facilities are generally less significant than effluent-generated emissions and may only be of interest to countries with centralized and advanced wastewater treatment facilities with controlled nitrification and denitrification capabilities. The overall emission factor for estimating N_2O emissions from such facilities is 3.2 g N_2O/person/year. This factor was determined in tests conducted at a domestic wastewater treatment plant in the northern United States (Czepiel et al., 1995). Emission data were obtained at a facility that received only domestic wastewater. This wastewater already included unconsumed protein but not the industrial and commercial wastewater discharged together. No other country emission factors are available. N_2O emissions from centralized wastewater treatment processes are calculated as follows:

ÉQUATION 6.9
EMISSIONS DE N_2O ISSUES DE PROCESSUS CENTRALISES DE TRAITEMENT DES EAUX USEES

$$N_2O_{INSTALLATIONS} = P \bullet T_{INSTALLATION} \bullet F_{IND-COM} \bullet EF_{INSTALLATION}$$

Where:

N2O *INSTALLATIONS* = total N_2O emissions from facilities in the inventory year, kg N_2O/year
P = total population
T INSTALLATION= degree to which modern, centralized facilities are used, %.
F IND-COM= fraction of commercial and industrial protein released in a mixed manner (default = 1.25, based on Metcalf & Eddy (2003) and expert judgment) [d] EF INSTALLATION= emission factor, 3.2 g N_2O/person/year

Note: If a country chooses to include N_2O emissions from facilities, the amount of nitrogen associated with these emissions (N_{WWT}) must be back-calculated and then subtracted from $N_{EFFLUENT}$. The N_{WWT} can be calculated by multiplying N_2O INSTALLATIONS by 28/44, using the molecular weight.

Table 9: Default Data for the N_2O Methodology

	Définition	Valeur par défaut	Gamme
Facteur d'émission			
$EF_{EFFLUENT}$	Facteur d'émission, (kg N_2O-N/kg –N)	0,005	0,0005 – 0,25
$EF_{INSTALLATIONS}$	Facteur d'émission, (g N_2O/personne/an)	3,2	2 – 8
Données d'activité			
P	Population totale du pays	Valeur de pays	± 10 %
Protéine	Consommation annuelle de protéine par habitant	Valeur de pays	± 10 %
F_{NPR}	Fraction d'azote dans la protéine (kg N/kg protéine)	0,16	0,15 – 0,17
$T_{INSTALLATION}$	Degré d'utilisation de grandes installations WWT	Valeur de pays	± 20 %
$F_{NON-CON}$	Facteur à ajuster pour la protéine non consommée	1,1 pour les pays sans broyeurs d'ordures ; 1,4 pour les pays disposant de broyeurs d'ordures	1,0 – 1,5
$F_{IND-COM}$	Facteur permettant le rejet mixte d'azote industriel dans les égouts. Pour les pays possédant d'importantes usines de traitement du poisson, ce facteur peut être plus élevé. Jugement d'expert recommandé.	1,25	1,0 – 1,5

5. Emissions from Transport Vehicles

Emissions can be estimated based on either the fuels consumed (represented by the fuels sold) or the distance traveled by the vehicles. In general, the former approach (fuels sold) is appropriate for CO_2 and the latter (distance traveled by vehicle type and road type) is appropriate for CH_4 and N_2O.

CO_2 EMISSIONS

CO_2 emissions are best calculated using the amount and type of fuel consumed (which should be equal to the amount of fuel sold) and its carbon content. The following Figure 4 shows the decision tree for CO_2 that guides the selection of a Tier 1 or Tier 2 method. Each method is defined below.

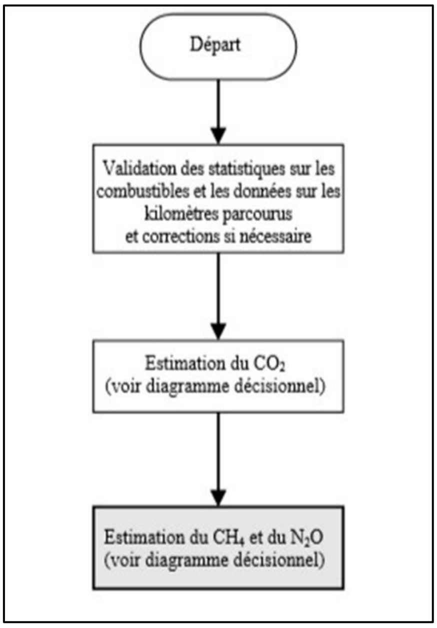

Figure 4: Steps for Estimating Vehicle Transport Emissions

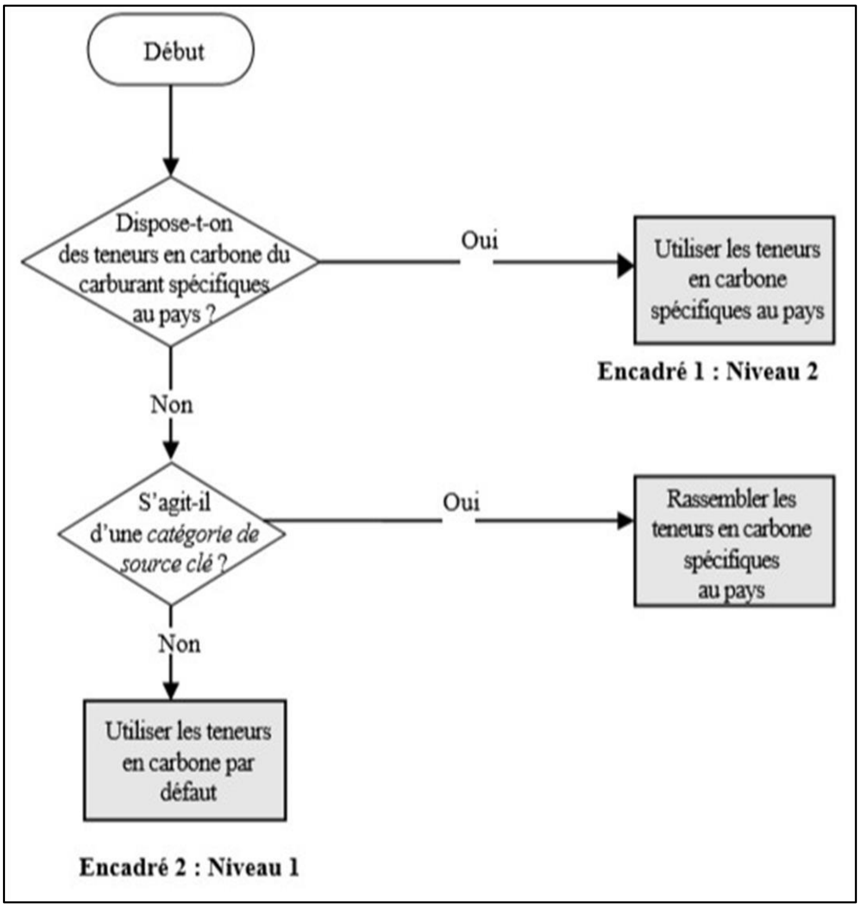

Figure 5: Decision Tree for CO_2 Emissions from Fuel Combustion in Road Vehicles

The Tier 1 approach calculates CO_2 emissions by multiplying the estimated amount of fuel sold by a default CO_2 emission factor. This approach is represented by Equation 3.2.1.

ÉQUATION 3.2.1
CO_2 IMPUTABLE AU TRANSPORT ROUTIER

$$Emission = \sum_a [Carburant_a \bullet EF_a]$$

Where:

Emission= CO2 emissions (kg) Fuel= fuels sold (TJ)
EFa = emission factor (kg/TJ). It is equal to the carbon content of the fuel multiplied by 44/12. a = type of fuel (e.g. gasoline, diesel, natural gas, LPG, etc.)

The CO_2 emission factor takes into account all the carbon in the fuel including that emitted as CO_2, CH_4, CO, NMVOCs and particulate matter.

CH4 AND N2O EMISSIONS

CH_4 and N_2O emissions are more difficult to estimate accurately than CO_2 emissions because emission factors depend on vehicle technology, fuel and operating characteristics. Data based on distance (e.g., vehicle miles traveled) and disaggregated fuel consumption may be much less certain than data on total fuel consumption. CH_4 and N_2O emissions primarily depend on the distribution of emission control technologies across vehicle fleets. For this reason, the upper tiers use an approach that considers populations of different vehicle types and their various pollution control technologies. Although CO_2 emissions from biogenic carbon are not included in the national totals, the combustion of biofuels in mobile sources produces anthropogenic CH_4 and N_2O that must be calculated and reported in the emissions estimates. The decision tree in Figure 6 presents the method used to calculate CH_4 and N_2O emissions. The inventory agency should choose the method based on data availability and quality. The equation for the Tier 1 method for estimating CH_4 and N_2O from road vehicles can be expressed as follows:

$$\text{ÉQUATION 3.2.3}$$
$$\text{ÉMISSIONS DE NIVEAU 1 DE } CH_4 \text{ ET DE } N_2O$$
$$Emission = \sum_a [Carburant_a \bullet FE_a]$$

Where:

Emissions = emissions in kg EFa =
emission factor (kg/TJ).
Fuel = fuel consumed, (TJ) (as represented by the amount of fuel sold) a = fuel type a (e.g. diesel, gasoline, natural gas, LPG)

Equation 3.2.3 for the Tier 1 method consists of the following steps:

- Step 1: Determine the amount of fuel consumed by fuel type for road transportation using national data or, alternatively, international data sources from the IEA or the UN (all values should be presented in terajoules).
- Step 2: For each fuel type, multiply the amount of fuel consumed by the appropriate default CH_4 and N_2O emission factors.
- Step 3: The emissions of each pollutant are summarized for all fuel types. The emissions equation for Tier 2 is as follows:

$$\text{ÉQUATION 3.2.4}$$
$$\text{ÉMISSIONS DE NIVEAU 2 DE } CH_4 \text{ ET DE } N_2O$$
$$Emission = \sum_{a,b,c} [Carburant_{a,b,c} \bullet FE_{a,b,c}]$$

Where:

Emission = emission in kg
EFa,b,c = emission factor (kg/TJ).
a = fuel type (e.g. diesel, gasoline, natural gas, LPG)
b = vehicle type
c = emission control technology (e.g. uncontrolled, catalytic converter, etc.)

For the selection of emission factors, one can choose between default (Tier 1) or country-specific (Tier 2 and Tier 3) emission factors based on the application of decision trees that examine the type and level of disaggregation of the activity data available for Senegal.

Table 10: Default CO_2 Emission Factors and Uncertainty Ranges for Transport

Type de carburant	Valeur par défaut (kg/TJ)	Limite inférieure	Limite supérieure
Essence automobile	69 300	67 500	73 000
Gasoil / Diesel	74 100	72 600	74 800
Gaz de pétrole liquéfiés	63 100	61 600	65 600
Kérosène	71 900	70 800	73 700
Lubrifiants [b]	73 300	71 900	75 200
Gaz naturel pour véhicules	56 100	54 300	58 300
Gaz naturel liquéfié	56 100	54 300	58 300

Source : Tableau 1.4 du chapitre Introduction du Volume Énergie.

Notes :

[a] Les valeurs représentent une oxydation à 100 pour cent de la teneur en carbone du carburant.

[b] Voir Encadré 3.2.4 Lubrifiants dans la combustion mobile pour des recommandations sur l'utilisation des lubrifiants.

Table 11: Default Emission Factors and Uncertainty Ranges for N_2O and CH_4 for Transport

Type de carburant/catégorie représentative de véhicule	CH_4 (kg/TJ)			N_2O (kg/TJ)		
	Valeur par défaut	Limite inférieure	Limite supérieure	Valeur par défaut	Limite inférieure	Limite supérieure
Essence automobile – non contrôlé [(b)]	33	9,6	110	3,2	0,96	11
Essence automobile –Catalyseur à oxydation [(c)]	25	7,5	86	8,0	2,6	24
Essence automobile – véhicule utilitaire léger à faible kilométrage de 1995 ou plus tard [(d)]	3,8	1,1	13	5,7	1,9	17
Gasoil/Diesel[(e)]	3,9	1,6	9,5	3,9	1,3	12
Gaz naturel [(f)]	92	50	1 540	3	1	77
Gaz de pétrole liquéfiés [(g)]	62	na	na	0,2	na	na
Éthanol, camions, États-Unis [(h)]	260	77	880	41	13	123
Éthanol, voitures, Brésil [(i)]	18	13	84	na	na	na

6. Emissions from Energy Consumption or Stationary Combustion

The methods and data needed to estimate emissions from stationary combustion, along with the categories in which these emissions are proposed for the sector-based approach, are divided into three tiers based on the following:

- Tier 1: Fuel combustion based on national energy statistics and default emission factors;

- Tier 2: Fuel combustion based on national energy statistics and country-specific emission factors obtained, where possible, from national fuel characteristics;
- Tier 3: Fuel statistics and combustion technology data applied simultaneously with technology specific emission factors. This includes the use of models and facility-level emissions data where available.

The sections on Tier 1 present the steps required for the simplest calculation methods, or the methods that require the least data. These methods typically yield the least accurate emissions estimates. Tier 2 and Tier 3 approaches require more detailed resources and data (time, expertise, and country-specific data) to estimate emissions. If properly applied, the higher tier methods should be more accurate.

Tier 1 Approach

For a Tier 1 emissions estimate, the following data are required for each source category and fuel type:

- Data on the amount of fuel burned in the source category
- A default emission factor

ÉQUATION 2.1
ÉMISSIONS DE GAZ A EFFET DE SERRE IMPUTABLES A LA COMBUSTION STATIONNAIRE

$$Emissions_{GES,comb.} = Consommation\ combustible_{comb.} \bullet Facteur\ d'émission_{GES,comb.}$$

Where:

Combined GHG emissions = emissions of a given greenhouse gas by fuel type (kg GHG)
Combustible consumption = amount of fuel burned (TJ)
GHG emission factor, comb. = default emission factor of a given GHG by fuel type (kg gas/TJ). For CO_2, it includes the carbon oxidation factor, estimated to be 1

To calculate the total emissions per gas attributable to the source category, the emissions as calculated in Equation 2.1 are summed for all fuels:

ÉQUATION 2.2
ÉMISSIONS TOTALES PAR GAZ A EFFET DE SERRE

$$Emissions_{GES} = \sum_{combustibles} Emissions_{GES,\ combustible}$$

Tier 2 Approach

The Tier 2 approach requires the following data:

- Data on the amount of fuel burned in the source category;

- A country-specific emission factor for the source category and fuel for each gas.

With the Tier 2 approach, the default Tier 1 emission factors in Equation 2.1 are replaced by country-specific emission factors. Country-specific emission factors can be developed by taking into account country-specific data, e.g. carbon content of the fuels used, carbon oxidation factors, fuel quality and (for non-CO_2 gases in particular) the state of technological development. Emission factors may change over time and, for solid fuels, must take into account the amount of carbon retained in the ash, which may also change over time.

Tier 3 Approach

The Tier 1 and Tier 2 approaches described in the previous sections use an average emission factor for a source category and the fuel mix in the source category. In reality, emissions depend on the following factors:

- the type of fuel used,
- the combustion technology,
- operating conditions,
- the control technology used,
- maintenance quality, and
- the age of the equipment used to burn the fuel.

With the Tier 3 approach, this is taken into account by breaking down the fuel combustion statistics between the various alternatives and using emission factors that are based on these differences.

CHAPTER II: GHG EMISSIONS RESULTS

1. GHG Emissions Balance (in 2015)

This sector is dedicated to the treatment and discharge of domestic wastewater. It includes:

- Emissions from major water collection and treatment processes (river flow, closed and underground sewers, open sewers, WWTPs, FSTP, temporary water bodies, anaerobic lagoons, septic tanks and open pits[2] and latrines, open defection);

- The incineration of the sludge of the WWTP or FSTP ;

- Energy use (transportation and electricity).

The total GHG emissions of the sanitation sub-sector in Senegal amounted to 1257 Gg $eqCO_2$ in 2015. Furthermore, the results of the inventory show:

- The prevalence of methane (CH_4) emissions, which reached 944.86 Gg CO
- Nitrous oxide emissions amounted to 303.47 Gg $eqCO_2$, which represents 24% of the total emissions;
- Carbon dioxide (CO_2) is less represented in the inventories; it is estimated at 8.98 Gg $eqCO_2$, or 0.71% of total emissions;
- Emissions from all sources of GHG emissions are on the rise over the entire 2015-2030 period.
- The energy sector is almost the only contributor to carbon dioxide (CO_2) emissions, with a value of 8.97 Gg in 2015. These emissions are mainly generated by transportation activities and to a lesser extent by the supply of electrical energy. They are increasing considerably over time. The CO_2 emissions are mainly related to diesel consumption by emptying trucks for on-site sanitation. Emissions generated by sludge incineration activities and electricity consumption are marginal, as shown in *Figure 6*..
- They are virtually twice as high as emissions from septic tanks and three times as high as emissions from FSTP and WWTPs. FSTP and WWTP emissions are in the same order of magnitude for the year 2015. The predominance of emissions from traditional latrines can be attributed to their significance in rural areas and the virtual absence of emptying systems, which prolongs the residence time of sludge and facilitates intense and prolonged fermentation and digestion.

Figure 6: GHG Emissions by Type of Sanitation in Gg - 2015

Figure 7 below illustrates the aggregate GHG emissions by type of sanitation, treatment, or discharge. Latrines are the primary source of GHG emissions,

[2] Open pits are actually sanitation devices similar to latrines

454.26 Gg CO_2e overall. WWTPs are next (265.04 Gg CO_2e), followed by septic tanks (198.05 Gg CO_2e), etc.

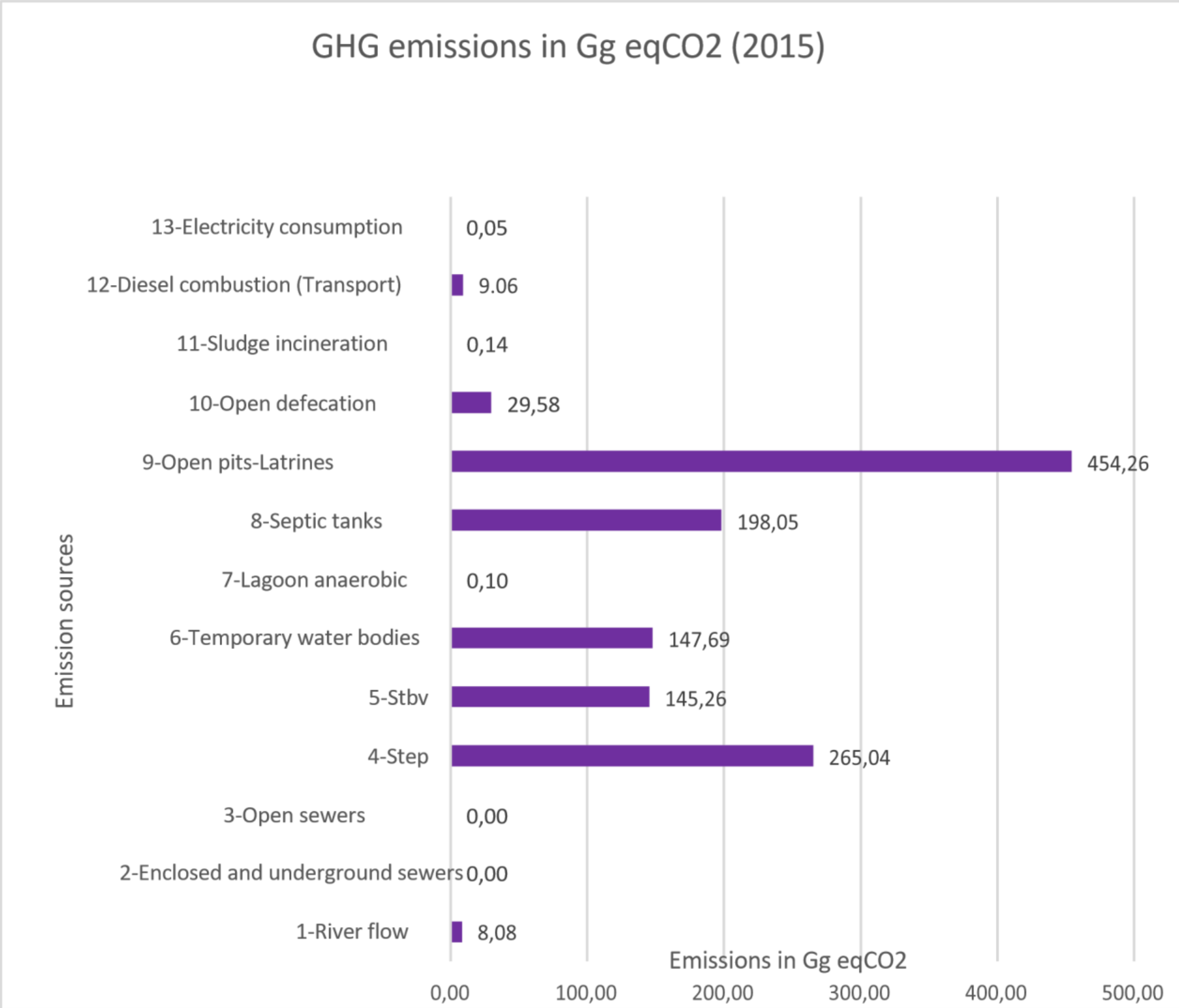

Figure 7: GHG Emissions in Gg CO_2e - in 2015

2. Emissions by Type of GHG from 2015 to 2030

The results of the reference year, below (Table 12), show a predominance of methane emissions (which average 75.15%), followed by nitrous oxide (with an average percentage of 24.14%) and finally carbon dioxide, which accounts for 0.71% (see *Figure 8*).

Table 12: GHG Emissions Balance of the Liquid Sanitation Sub-sector in Senegal (2015 to 2030)

Total GHG Emissions (Gg eqCO_2) (2015 - 2030)								
Years	2015		2020		2025		2030	
GHG	Value	%	Value	%	Value	%	Value	%
CO_2	8.98	0.71	10.58	0.63	13.64	0.68	16.27	0.77
CH_4	944.86	75.15	1,161.69	69.62	1,427.48	70.80	1,496.04	70.84
N_2O	303.47	24.14	496.32	29.74	575.06	28.52	599.57	28.39
Total	1,257.30	100.00	1,668.59	100.00	2,016.17	100.00	2,111.87	100.00

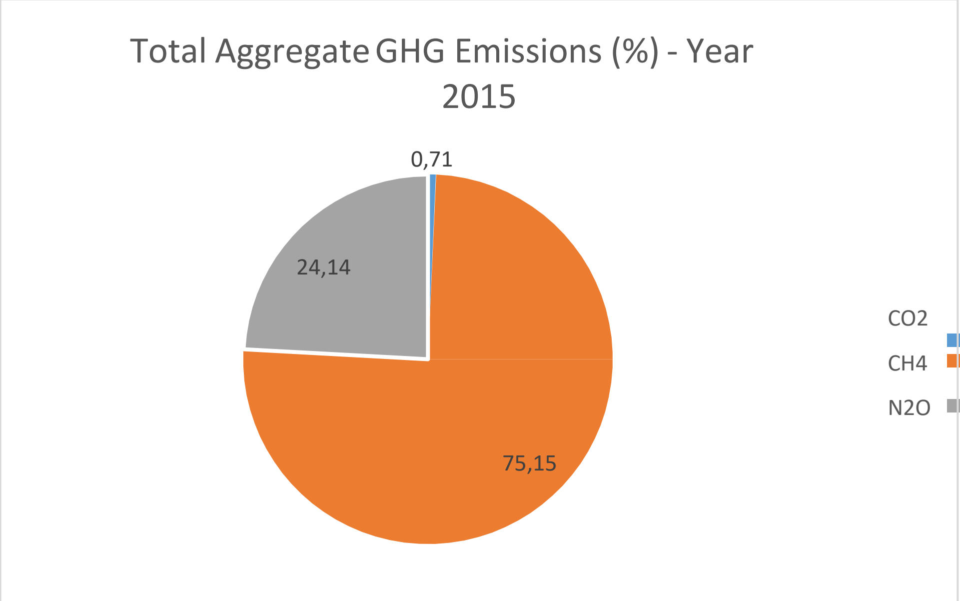

Figure 8: Total GHG Emissions in Gg CO_2e (%) in 2015

3. GHG Mitigation Options and Potential

Table 13 below lists all projects and programs in the sanitation sub-sector that have the potential to mitigate or reduce GHG emissions. Some of these options are "unconditional" while others are "conditional".

Table 13: GHG Mitigation Options and Potential for Projects and Programs

GHG Mitigation Options and Potential for Projects and Programs				
Conditional Mitigation Options	GHG emission reduction potential over time (%)			
Periods	2015	2020	2025	2030
Unconditional Mitigation Options (UMO)				
1- Hann Bay clean-up project	0%	3%	10%	13%
2-Dakar North clean-up project				
3-Project to clean up ten cities in Senegal				
4-Sanitation project in Cité Soleil and its surroundings.				
5-Sanitation project in Fatick, Ziguinchor and Joal-Fadiouth				
6-Network renewal in Dakar.				
7-Sanitation project in 05 cities				
8-Construction of 04 public water kiosks in Touba				
9-Construction of a sludge treatment plant in Touba				
10-Social connections project in regions.				
10-Wastewater sanitation works in Almadies in Dakar				
11-Structuring of the fecal sludge market (PSMBV) in the suburbs of Dakar				
Conditional Mitigation Options (NDC+)				
1-Installation of new WWTP in the cities of Kolda, Nioro and Bakel	0%	10%	15%	20%
2-Study of eighteen (18) sanitation master plans (SDA) in Senegal				
3-Project for the renewal of the sewerage network of the Island of Saint Louis				
4-Project to upgrade and reinforce stormwater management facilities in Dakar				
5-Projects for wastewater treatment in Pikine irrégulier Sud (PIS 2)				
6-Strategic study on the contribution of the sector to adaptation and mitigation efforts in progress and/or planned for the pre-2020 and post2020 phases				

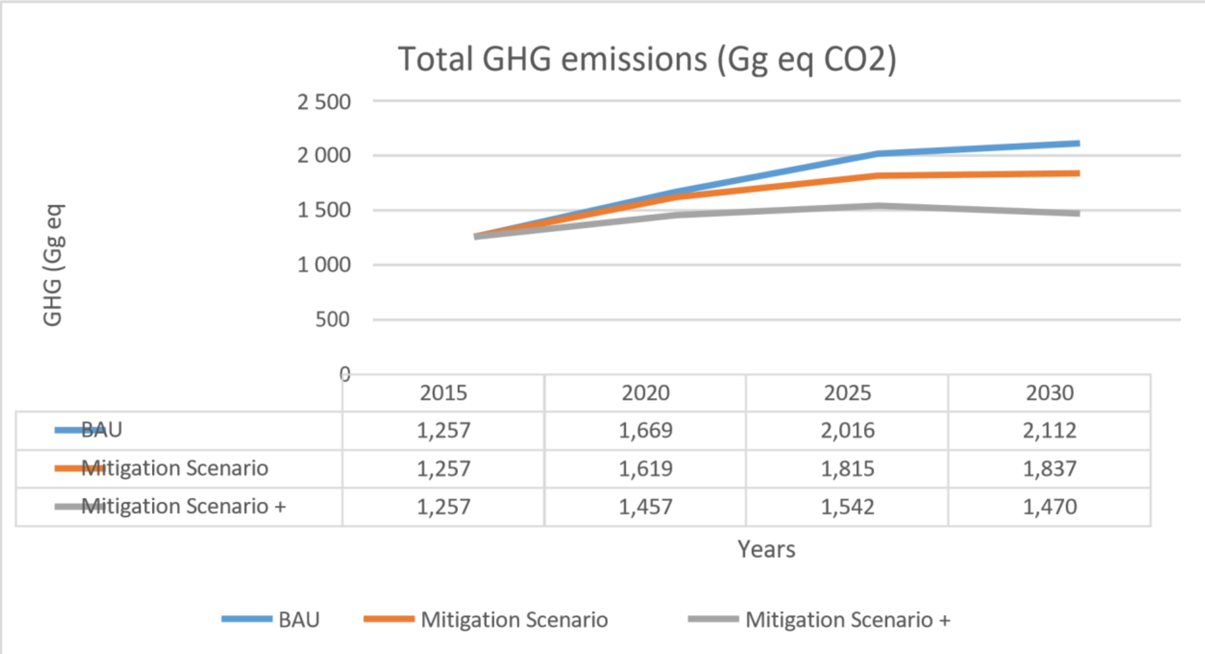

Figure 8: Projected GHG Emissions under Various Mitigation Scenarios

Mitigation scenario: consists of the implementation of projects and programs whose financing is entirely controlled by the Senegalese government. There is an increase at this level, but it is still below the BAU trajectory.

Mitigation+ scenario: consists of the implementation of projects and programs financed by donors and multilateral partners. There is decrease in emissions from 2030 onwards which is also below the trajectory of the mitigation scenario.

4. Difference with the Previous Inventory

The methods implemented are consistent with the 2006 IPCC guidelines and the approaches implemented are Tier 1 methods based mostly on data from available literature. This inventory of GHG emissions from the wastewater treatment subsector is much more comprehensive than the previous one, which was conducted under the NDC in 2015. This is because virtually all potential sources of GHG emissions are identified and covered by the study.

Comparison with the results of the NDC (2015) (*Table 15*), with 2010 as the base year, shows a significant increase in GHG emissions. According to the NDC, total GHG emissions from the liquid sanitation subsector are only 164.26 Gg eqCO_2 (or 1.01% of national emissions, all sectors combined). This relatively low value is mainly due to the fact that the study was not exhaustive and lacked precision. Indeed, only collective sanitation was covered by the study. In fact, GHG emissions from the sanitation sub-sector, all sources combined, are far from marginal.

They represent 1257.30 Gg eqCO_2 in 2015 (or 7.74% of national emissions).

Table 14: Comparison of Results Obtained with the NDC

Comparison of Results Obtained with the NDC		
Studies	**Emissions**	
	Gg eqCO_2	%
National emissions - NDC	16247,00	100,00
Waste-generated emissions (solid and liquid)	1820,80	11,21
-Liquid waste NDCemissions - NDC	164,26	1,01
2020 Sanitation Study - GGGI	1257,30	7,74

The main changes to be made in order to improve the wastewater inventory must focus on the following:

- Access to data on treatment plants (N and BOD5 input, N and BOD5 discharge into the natural environment, type of treatment, etc.) and in accordance with the requirements of the IPCC methods, Tier 2 or Tier 3 ;
- Data specific to the sanitation sector could be collected systematically at the national level through an annual survey. This would enhance the methodology applied.

CHAPTER III: MITIGATION AND ADAPTATION MEASURES

1. Mitigation Measures

To reduce the risks associated with climate change, two complementary approaches can be implemented: mitigation, with the purpose of combatting global warming by reducing the production of GHGs, and adaptation, which is about reducing systems' exposure level and their vulnerability.

The issue of mitigation for sanitation purposes requires a three-pronged approach:

- Limiting the release of greenhouse gases (methane and nitrous oxide) into the atmosphere by wastewater and excreta, and therefore choosing the most appropriate type of sanitation and treatment processes;
- Methane capture and energy recovery;
- The implementation of energy-efficient sanitation value chains (transport and treatment).

This includes reducing energy consumption and making significant use of renewable resources. Pursuing this goal also reduces local expenses and ensures services are sustainable. The positive impacts of mitigation are perceived on a global scale, which requires a collective effort to effectively address rising temperatures on a global scale.

The measurement of the emission rates of the various GHGs should be a prerequisite to the implementation of a mitigation strategy and plan. This will make it possible to identify the areas with the highest emissions throughout the sanitation chain and therefore better assess the challenges facing the value chain, and better prioritize actions. From a practical point of view, measurement and optimization will lead to a significant reduction in GHG emissions. To this end, the first priorities for reflection are as follows.

<u>For the non-collective sanitation system:</u>

Thus, optimizing and reducing transport distances is an important leverage for reducing emissions. This can be achieved by building small decentralized treatment systems close to residential areas. Regular maintenance of the vehicle fleet and the selection of vehicles with more efficient engines can also help to keep GHG emissions as low as possible. In terms of excreta collection, efforts can be made to reduce the volumes to be transported: giving priority to on-site treatment, encouraging separate systems when this solution is appropriate (e.g. urine-diverting toilets for agricultural reuse, separation of grey water for treatment and sump infiltration, etc.).

<u>For the collective sanitation system:</u>

Reducing volumes to be treated is also a leverage for mitigation: raising user awareness of water conservation and water efficiency can reduce both grey water and black water volumes if dual flush toilets are used. To reduce the energy consumption of lifting pumps, the design of wastewater evacuation networks (sewers) must prioritize gravity flow systems. The implementation of mitigation actions must also be considered in relation to stormwater management. Separate systems should be preferred in the design of services. Where this is not the case, some nature-based alternatives may be used to facilitate stormwater infiltration and thereby reduce the volume of wastewater to be treated.

1.1. Mitigation Measures to be Adopted

The sanitation sector is not considered to be a major source of greenhouse gas emissions. Mitigation actions are mainly based on the use of cleaner energy sources and reduced consumption. For sanitation, limiting the release of methane (through appropriate treatment processes), establishing energy-efficient processes, and capturing and recovering methane (biogas) can help mitigate emissions.

The purpose of mitigation for wastewater services is to reduce direct and indirect GHG emissions. The steps to be pursued for mitigation are as follows:

- First, it is necessary to assess GHG emissions and identify the largest contributors to emissions.
- Therefore, understanding quantified information on GHG production should make it possible to define a mitigation strategy.
- Finally, the development of an action plan will make it possible to determine the various stages of the implementation process.

1.2. Sources of Greenhouse Gas Emissions

The main sources of greenhouse gas emissions for off-site sanitation are the wastewater aeration systems in plants and pumping activities in networks. With regard to on-site sanitation, the transportation of sludge by truck as well as the sludge treatment processes can be significant sources of emissions. The main GHG emissions are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide
(N_2O).
The main sources of GHG emissions for sanitation are as follows:

- Energy consumption (electricity, fuel oil, natural gas), since energy production causes GHG emissions,
- The discharge of wastewater and excreta - which are natural sources of GHG emissions - and their treatment processes.

Measuring the emission rates of the various GHGs should be a prerequisite for the implementation of a mitigation strategy and plan. This will make it possible to identify the most significant sources of emissions throughout the sanitation chain and therefore better assess the challenges facing the value chain, and better prioritize actions. From a practical point of view, measurement and optimization can lead to a significant reduction of GHG emissions..

1.3. Supporting Transitions

Adaptation or mitigation approaches must be supported and accompanied throughout their implementation. Guaranteeing an environment that is suitable for the emergence of such approaches requires :

- Adapting the framework for public action: Implementing adaptation or mitigation actions sometimes presupposes adjustments to the legislative and regulatory framework in order to meet these new challenges. For sanitation, this applies in particular to the regulation and support of public authorities on the use of wastewater treatment by-products and the reuse of treated wastewater (agricultural spreading of sewage sludge, biogas recovery, etc.). Financial incentives for investment in efficient equipment can be an important leverage for mobilization, when supported by the State through its local authorities or decentralized services.
- The issue of climate-related financing: The issue of climate-related financing is also the focus of considerable debate, especially within international bodies. If economic and societal transition is necessary, it requires substantial financing. Mitigation requires a profound change in energy systems. It also has an economic cost that most developing countries are unable to bear, while they are already facing a number of socio-economic difficulties. The development of financing mechanisms to fight against climate change and its effects is becoming necessary. There are international financing mechanisms, such as the Green Climate Fund attached to the UNFCCC and the Adaptation Fund provided for by the Kyoto Protocol, but they are difficult to access and are dedicated to large-scale projects. Other financing mechanisms exist, with a number of multilateral and national funds integrating climate change considerations into their activities. However, some countries are finding it difficult to access these funding streams. This is especially true when it comes to financing adaptation projects. Most of the funds have limited access due to complex procedures and some cannot be directly mobilized by these countries, which must turn to international financial institutions or regional banks. Some countries have inadequate national frameworks, which makes it more difficult for them to obtain funding: a poorly adapted legal framework, the absence of a national strategy on climate change, and a lack of skills and technical and financial management.

- Guaranteeing concerted approaches: Concerted action makes it possible to collectively define the most appropriate technical solutions and organizational and legislative measures for the development of the sector. These "principles and values", which are universally shared and promoted, ensure strong and effective master plans. The consultation process is as important as the strategy document because it plays an educational and collective role of learning, information and reflection, thereby facilitating ownership by all stakeholders and populations in particular. Participation and consultation dynamics are essential in a context of climate change: they allow everyone to take ownership of the challenges of climate change and to build a shared vision for the implementation of adaptation and mitigation actions that result from it. The approach also provides an opportunity to promote experience sharing and to raise awareness of issues encountered in order to improve processes as activities are implemented.

1.4. Towards a Circular Economy for Sanitation Services

Mitigation for the sanitation sector is well suited to the application of circular economy principles. This approach encourages a shift in mentalities by considering wastewater and treatment by-products as resources. The use of these resources must be considered in synergy with other actors and services: the energy sector, the agricultural sector, solid waste management, etc. The resources to be considered include: The concept of circular economy refers to an economic model of exchange and production that aims to increase resource use efficiency and decrease our impact on the environment. The water sector is particularly suited to a circular economy vision, where the products of sanitation can be valorized in agriculture or energy production. The development of a circular economy requires a favorable environment for the implementation of new practices and a change of mentality to consider sanitation products as resources. Their recovery must meet the demand (which can itself be generated) in order to be economically viable.

Different mechanisms can be used to support this process, especially regulation and market economy related mechanisms. The thermal potential of wastewater effluents includes:

- Use of network waste heat for energy production purposes;
- Production of green energy through the supply of biomass fuel or the reuse of biogas;
- Recovery of nutrients from wastewater treatment or excreta in agriculture, allowing collaborations with the waste sector (reuse of green waste as input for co-composting).

2. Adaptation Measures

2.1. Adaptation through a Sanitation Value Chain Analysis Approach

Adaptation to climate change is defined as the process of adjusting to the current or expected climate and its consequences. In human systems, it involves mitigating or avoiding adverse effects and exploiting beneficial effects. In some natural systems, human intervention can facilitate adaptation to the expected climate as well as its consequences (Source: IPCC, 2014). Adaptation also refers to adjustments in ecological, social, or economic systems in response to actual or expected climate stimuli and their effects or impacts. It involves changes in processes, practices, and structures to moderate potential damages or to take

advantage of opportunities associated with climate change. In simple terms, countries and communities must develop an adaptation solution and implement actions to respond to climate change impacts that are already occurring, as well as prepare for future impacts.

With respect to sanitation, adaptation options in the sanitation value chain can be broken down as follows:

For collective sanitation

The adaptation strategy will focus on emissions related to the following:

- Collection: the public sewerage system collects domestic wastewater and wastewater from professional activities (crafts, restaurants, authorized industry.);
- Transport through pipe systems;
- Treatment (water and sludge) in a wastewater treatment plant (sewage plant);
- Discharge into the natural environment.

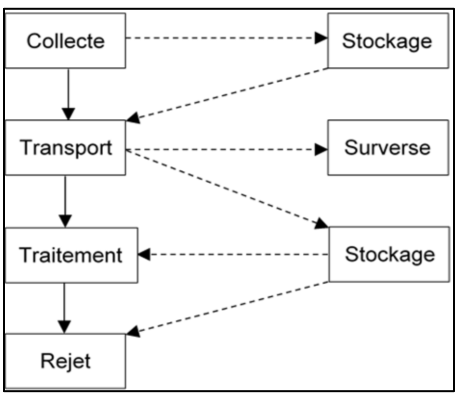

Figure 9: Wastewater Treatment Value Chain (excluding sludge recovery)

Figure 10: Urban Water Treatment Processes (excluding by-product reuse)

For on-site or semi-collective sanitation

The adaptation strategy will focus on emissions related to the following five (05) steps:

- User interface: family latrine
- Collection and storage/processing
- Transport
- (Semi-)centralized processing
- Recovery and/or landfill

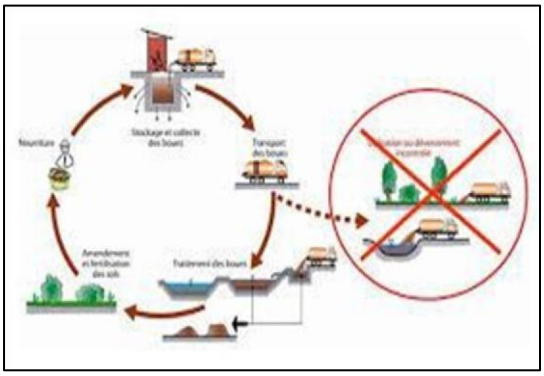

Figure 11: Adaptation Strategy and Sanitation Value Chain

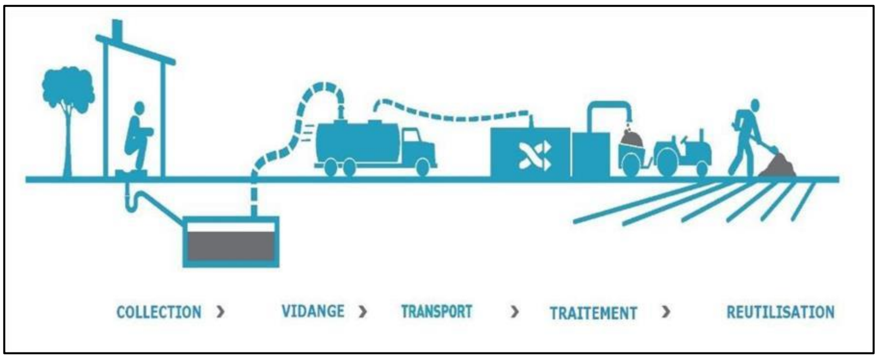

Figure 12: On-site Sanitation Value Chain

2.2. Risk and impact assessment methods

Risks caused by hazards and climate change can be reduced through climate change adaptation and disaster risk management. There are differences and similarities between these two approaches. While adaptation focuses on gradual and continuous changes over the long term, such as sea level rise, or changes in precipitation patterns, DRM focuses on prevention, preparedness, and response to the potential occurrence of hydrometeorological events related to climate variation and geological events.

The main objective of the rapid analysis is to identify risks in a systematic and rigorous manner, while remaining simple and fast. This analysis will determine the types of activities that have a potential to cause disasters and those that do not.

Focusing on a series of issues makes it possible to conduct a qualitative risk analysis. These issues are organized into four categories: 1) Hazards and Exposure, 2) Impacts and Vulnerabilities, 3) General Estimate of Risk to the Activity, and 4) Whether or not to undertake a detailed risk analysis.

For reference purposes, below are some of the major risks, including but not limited to:

- Temperature increase;
- Flooding;
- Coastal erosion;
- Deterioration of surface water quality due to water pollution;
- Drought.

The guide is based on the technique of Failure Modes, Effects and Criticality Analysis (FMECA). This approach consists in identifying, within a technological system, the potential failure modes of its elements, their causes and effects. Its aim is to measure the level of criticality of the sanitation installations for which improvement actions must be implemented.

2.3. Analysis Results and Proposed Adaptation Measures

Climatic hazards also have direct impacts on the operation of the sanitation service itself, as far as treatment is concerned, but also to the service access and evacuation infrastructures. The following table summarizes the links between climatic phenomena and the technical, social, health and environmental consequences in sanitation services.

2.3.1. Specific Adaptation Measures by Value Chain

The analysis of the links between climate and drinking water and sanitation services and the identification of various response frameworks highlight certain actions associated with governance, around and within water and sanitation services, but also more technical and specific solutions.

Table 15: Specific Adaptation Measures by Value Chain

		Impacts	Adaptation
Heat wave	**Collective Sanitation** (Sewerage)		
	WWTP Closed and underground sewers River flow	- Dysfunctional biological treatment processes (mortality of certain bacteria). - Degradation of infrastructure and equipment due to heat - Degradation of concrete due to increased production of hydrogen sulfide (H_2S) - High methane production poisoning by inhalation of hydrogen sulphide (H_2S) whose production is increased by heat Safety risks for personnel, especially sewage workers - Odor nuisance due to increased N_2O emissions - High carbon dioxide (CO_2) emissions	Anti-corrosive infrastructure and equipment - Waterproofing of infrastructure - Control and elimination of hydrogen sulfide (H_2S) and nitrous oxide (N_2O) - Regular control of the processes and evolution of these treatments towards systems adapted to the new climatic conditions - Wearing of personal protective equipment (PPE) for exposed personnel and sewage workers
	On-site sanitation		
	Latrine and septic tanks FSTP Water bodies Septic tanks Open defecation	See below	See below
	Other		
	Sludge incineration Transport	See below	See below
Intense Rain Episode/Flooding/Storms	**Collective sanitation**		
	WWTP Closed and underground sewers River flow	Failure of equipment and other electrical systems in wastewater treatment plants, making them inoperative	- Increase the rate of wastewater treatment before discharge into waterways
	On-site sanitation		

	Latrine and septic tanks FSTP Water bodies Septic tanks Open defecation	- Destruction of substandard latrines (impact on access rates can be significant) - Stormwater intrusion in sewage systems - Development of water-borne diseases - Impoverishment of vulnerable groups through loss of economic activity	- Limitation of sludge retention time Valorization bydomestic biomethanizer for cooking use - Recovery of sludge in agriculture after composting - Limitation of sludge retention time - Secondary purification by phytoplankton Vehicle fleet to be reviewed and amortized within a reasonable time frame Sub-regional vehicle assembly plant - Zoning to limit travel distances within a specific radius
	Other		
	Sludge incineration Transport	- Increase in air pollution - Spread of diseases due to airborne particles - Frequent work accidents	Installation of (i) an on-site production system (generator with fuel stock accessible in the event of flooding in a protected room) and (ii) installation of equipment electromechanical equipment (motors, control panels) above the probable flood level Build stakeholder training and awareness

Table 16: Environmental Protection Adaptations

Climatic Hazards	Impacts	Adaptation Measures
• **Drought, lack of water**	- Degradation of the quality of the resource due to reduced pollutant dilution	- Improvement of wastewater treatment capacity before discharge into the natural
• **Intense and sudden rain episode, flooding** • **Storm**	- Increase in untreated discharges into the natural environment due to stormwater entering the wastewater system, causing overflow of wastewater systems, saturation of collection pumps and bypassing of treatment plants - Drainage of the wastewater/rainwater mixture on public roads due to flooded latrine pits and toilets, with health risks as consequences	- Setting up of separat e networks (storm and wastewater) - Limitation of stormwater intrusion into the wastewater system - Installation of buffer basins - Increased processing capacity - Placement of pits on raised ground or - Installation of tightly sealed pits

2.3.3. Adaptation Measures Related to Social and Health Impacts

Table 17: Adaptation Measures Related to Social and Health Impacts

Climatic Hazards	Impacts	Adaptation Measures
• **Heat wave**	- Poisoning by inhalation of hydrogen sulphide (H_2S), the production of which is increased by heat (risk in terms of safety for personnel, especially sewage workers) - Olfactory nuisance due to the increased emission of nitrogen dioxide (N_2O)	- Control and elimination of hydrogen sulfide (H_2S)
• **Intense and sudden rain episode, flooding** • **Storm**	- Population without sanitary facilities - Increase in waterborne diseases due to the risk of contact with water containing pathogens	- Emergency installation of temporary toilets until sanitary facilities are rebuilt - Emergency provision of quality water and home water treatment systems

2.4. Strategic Response Framework

Table 18: Strategic Framework for Adaptation Actions

Items	Description	Case of the Sanitation sector
Key questions	How can the adaptation plan be implemented in the context of a strategy? What are the responsibilities and strategic partnerships to be developed? How will actions be funded?	- Through better intentional framing around the DEEC - Strategic partners: DEEC, DA, GGGI, Private, ONAS, - Financing by the State of Senegal (MEF), the green fund or climate fund.
Recommended approach	Develop a strategy: Define the implementation or operationalization of the validated adaptation plan within the framework of a coherent strategy that is integrated with activities or projects related to the sanitation sector. In formulating this strategy, it is important to define "SMART" (Specific, Measurable, Attainable, Realistic, Time-bound) objectives, determine roles and responsibilities per measure, and plan the detailed process and timeline for implementing measures. Develop strategic partnerships Define funding strategies for the proposed measures Propose a way to strengthen the supply of services on climate change in the sanitation sector.	- Existing strategy through the NDC - Partners at the international level are to be identified by the DEEC - Establish a national financing strategy through climate funds.
Actors involved	Management structure Small working group Decision-makers Public funds, commercial banks Other organizations according to the themes of the adaptation measures	- All actors deemed relevant by DEEC as above. - ONAS, DA, Gates Foundation, Employers and industrialists, etc.
Potential activities	Awareness raising of the stakeholders involved in the implementation Networking to develop the necessary partnerships Overview of funding opportunities Identification of leaders/organizations responsible for implementing the measures	- Same
Tools	Strategic document that incorporates the adaptation plan and a timetable for implementing the measures Service offer presentation document (communication document that presents the services or activities that the management structure offers to its companies)	- Same

CONCLUSION

The development of water and sanitation services requires careful consideration of climate change and its effects. This is all the more urgent as failure to act will multiply future risks.

The sanitation sub-sector contributes significantly to greenhouse gas emissions related to waste. In Senegal, it represents nearly 7.74% of total greenhouse gas emissions, compared to 44.6% for agriculture and 33.8% for energy.

Mitigation actions must be based essentially on the use of cleaner energy sources and reduced consumption. This means giving priority to alternative energy sources (solar, wind, biogas), particularly for water treatment. Limiting the release of methane (via adapted treatment processes), setting up energy-saving processes and capturing and recovering methane (biogas) can help reduce emissions. With respect to adaptation measures, the sanitation sub-sector is very strongly impacted by climate change.

Adaptation for sanitation services will consist in improving the control and monitoring of the service as well as treatment, adapting infrastructure (expansion or flood protection) and implementing emergency actions.

A good understanding of the impacts and challenges is required before any action can be taken, in line with the global objectives of international and national frameworks and agreements (Paris Climate Agreement, MDGs). In this respect, adaptation and mitigation are two complementary approaches, allowing for different responses to reduce vulnerability in services.

A paradigm shift in priorities and practices is therefore necessary, in order to understand how to manage uncertainties related to climate scenarios and avoid maladaptation. The implementation of adaptation or mitigation activities requires the integration of climate risks in all approaches and at all levels. It must be facilitated by an initial diagnostic that allows for the assessment of vulnerability, exposure and the degree of risk for each hazard, both at the local and watershed levels.

Solutions must prioritize collaborative, multi-sectoral approaches and no-regrets actions. Already existing approaches such as integrated water resources management, nature-based approaches, water safety management plans or the concept of circular economy can contribute to the design of appropriate and sustainable solutions.

Finally, follow-up on initiatives taken and experience sharing among stakeholders must be strongly encouraged, just as research on the effects of climate change must be encouraged. Otherwise, promoting and improving practices will not be enough to develop long-term responses.

BIBLIOGRAPHY

Climate Change 2013. The science. Summary for Policymakers, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Published: IPCC, Switzerland.
Available at:
https://www.ipcc.ch/pdf/assessmentreport/ar5/wg1/WG1AR5_SPM_brochure_fr.pdf (Accessed: 16 June 2016) IPCC (2014).

Climate Change 2014. Climate Change Mitigation. Summary for Policymakers, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Published: IPCC, Switzerland. Available at:
https://www.ippc.ch/pdf/assessmentreport/ar5/wg3/WG3AR5_SPM_brochure_fr.pdf.GIEC (2014)

Climate Change, 2014. Impacts, Adaptation and Vulnerability. Summary for Policymakers, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
Published: IPCC, Switzerland. Available at:
https://www.ipcc.ch/pdf/assessmentreport/ar5/wg2/ar5_wgII_spm_fr.pdf .

Contribution déterminée au niveau national- CDN (2015). Rapport de consultation, sectoriel : déchets. Ministère de l'environnement et du développement durable – Sénégal. Revue Annuelle conjointe, 2018 [Nationally Determined Contribution- NDC (2015). Consultation report, sector: waste. Ministry of Environment and Sustainable Development - Senegal.
Joint Annual Review, 2018]. General Directorate of Planning and Economic Policies - Ministry of Economy, Finance and Planning - Republic of Senegal.

Czepiel et *al.* 1995. Nitrous oxide emissions from municipal wastewater treatment. Environ. Sci. Technol. 29 (1995): 2352-.

Sector Development Policy Letter (LPSD 2016 - 2025) (2016). Ministry of Water and Sanitation - Republic of Senegal.

IPCC Guidelines for National Greenhouse Gas Inventories - WASTE 6.3 Methane Emissions from Wastewater Treatment. Revised version 1996. Simplified Manual (Vol. 2) Published: IPCC, UK. Available at: http://www.ipcc- nggip.iges.or.jp/public/gl/pdfiles/en6-2.pdf IPCC (2006).

2006 IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas
Inventories Programme Authors: Michiel R. J. Doorn (The Netherlands), Sirintornthep Towprayoon
(Thailand), Sonia Maria Manso Vieira (Brazil), William Irving (United States), Craig Palmer (Canada), Riitta Pipatti (Finland) and Can Wang (China). Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/french IPCC (2008).

Metcalf & Eddy, Inc, 2003. Wastewater Engineering Treatment and Reuse. Fourth Edition. Available at:
https://ptabdata.blob.core.windows.net/files/2017/IPR2017-01468/V22_FWS1016%20- %20Metcalf.pdf.

National program for the sustainable development of on-site sanitation - PNDDAA (2019). ONAS -MHA- Senegal.

ONAS monthly and annual operating reports (2015 - 2020). IPCC Website:

http://www.ipcc.ch/report/ar5/wg1/.

Water science and Technology, Volume71,Issue7, Greenhouse gas emissions from sludge treatment reed beds ,
Yubo Cui; Shunli Zhang; Zhaobo Chen; Rui Chen; Xinnan Deng, April 2015 -
(https://iwaponline.com/wst/article-abstract/71/7/1011/18908/Greenhouse-gas-emissions-from-sludge- treatment?redirectedFrom=fulltext)

APPENDICES

1: GHG Emissions Result by Year (2015)

GHG emissions by category (in 2015)			
Categories	GHG emissions		
	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
4D1: Domestic wastewater treatment			
River flow	0	0.00	0.030
Closed and underground sewers	0	0.00	0.000
Open sewers	0	0.00	0.000
WWTP	0	4.20	**0.556**
FSTP	0	**5.19**	0.000
Temporary water bodies	0	0.00	0.557
Anaerobic lagoons	0	0.00	0.000
Septic tanks	0	7.07	0.000
Open pits/Latrines	0	16.22	0.000
Open defecation	0	1.06	0.000
Subtotal	**0**	**33.74**	**1.144**
4C1: Waste incineration			
Sludge incineration	0.000480924	0	0.001
Subtotal	**0.000480924**	**0**	**0.001**
1A:Energy			
Diesel combustion (Transport)	8.92537464	0.000469757	0.000
Electricity consumption	0.050874257	0	0.000
Subtotal	**8.976248897**	**0.000469757**	**0.000**
Total emissions	8.976729821	33.74489588	1.145
Total in CO_2eq (Gg)	8.976729821	944.8570847	303.470
Total aggregate CO_2eq emissions (Gg/year)	1 257		

2: GHG Emissions Result by Year (2020)

GHG emissions by category (in 2020)			
Categories	GHG emissions		
	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
4D1: Domestic wastewater treatment			
River flow	0	0,00	0,001
Closed and underground sewers	0	0.00	0.000
Open sewers	0	0.00	0.000
WWTP	0	5.85	**1.869**
FSTP	0	6.56	0.000
Temporary water bodies	0	0.00	**0.003**
Anaerobic lagoons	0	0.01	0.000
Septic tanks	0	7.81	0.000
Open pits/Latrines	0	20.29	0.000
Open defecation	0	0.97	0.000
Subtotal	**0**	**41.49**	**1.872**
4C1: Waste Incineration			
Sludge incineration	0.000553063	0	0.001
Subtotal	**0.000553063**	**0**	**0.001**
1A:Energy			
Diesel combustion (Transport)	10.5171612	0.000553535	0.001
Electricity consumption	0.061958592	0	0.000
Subtotal	**10.57911979**	**0.000553535**	**0.001**
Total emissions	10.57967285	41.48895465	1.873
Total in CO_2eq (Gg)	10.57967285	1161.69073	496.318
Total aggregate CO_2eq emissions (Gg/year)	1 669		

3: GHG Emissions Result by Year (2025)

GHG emissions by category (in 2025)			
Categories	GHG emissions		
	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
4D1: Domestic wastewater treatment			
River flow	0	0.00	**0.001**
Closed and underground sewers	0	0.00	0.000
Open sewers	0	0.00	0.000
WWTP	0	7.89	**2.166**
FSTP	0	7.62	0.000
Temporary water bodies	0	0.00	**0.002**
Anaerobic lagoons	0	0.01	0.000
Septic tanks	0	7.57	0.000
Open pits/Latrines	0	27.39	0.000
Open defecation	0	0.51	0.000
Subtotal	**0**	**50.98**	**2.169**
4C1: Waste Incineration			
Sludge incineration	0.000636022	0	0,001
Subtotal	**0.000636022**	**0**	**0,001**
1A:Energy			
Diesel combustion (Transport)	13.55861052	0.000713611	0.001
Electricity consumption	0.078442988	0	0.000
Subtotal	**13.63705351**	**0.000713611**	**0.001**
Total emissions	13.63768953	50.98135535	2.170
Total in CO_2eq (Gg)	13.63768953	1427.47795	575.055
Total aggregate CO_2eq emissions (Gg/year)	2 016		

4: GHG Emissions Result by Year (2030)

GHG emissions by category (in 2030)			
Categories	GHG emissions		
	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
4D1: Domestic wastewater treatment			
River flow	0	0.00	**0.000**
Closed and underground sewers	0	0.00	0.000
Open sewers	0	0.00	0.000
WWTP	0	9.85	**2.259**
FSTP	0	7.29	0.000
Temporary water bodies	0	0.00	**0.002**
Anaerobic lagoons	0	0.01	0.000
Septic tanks	0	6.74	0.000
Open pits/Latrines	0	29.23	0.000
Open defecation	0	0.31	0.000
Subtotal	**0**	**53.43**	**2.261**
4C1: Waste Incineration			
Sludge incineration	0.000731425	0	0,001
Subtotal	**0.000731425**	**0**	**0,001**
1A:Energy			
Diesel combustion (Transport)	16.17368844	0.000851247	0.001
Electricity consumption	0.094927384	0	0.000
Subtotal	**16.26861582**	**0,000851247**	**0.001**
Total emissions	16.26934725	53.42987401	2.263
Total in CO_2eq (Gg)	16.26934725	1496.036472	599.567
Total aggregate CO_2eq emissions (Gg/year)	2 112		

ABOUT THE GLOBAL GREEN GROWTH INSTITUTE

The Global Green Growth Institute was founded to support and promote a model of economic growth known as “green growth”, which targets key aspects of economic performance such as poverty reduction, job creation, social inclusion, and environmental sustainability.

The Global Green Growth Institute

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