Manual of Greenhouse Gas Inventory for Cities

Climate Change Secretariat

Ministry of Environment

Sri Lanka

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Manual & template developed by: Dr. Thusitha Sugathapala
Reviewed by: National Expert Committee on Climate Change Mitigation (2021)

Coordinators: Mr Sanjaya Kariyawasam, Deputy Director, Climate Change Secretariat
Ms Hasula Wickremasinghe, Programme Assistant, Climate Change Secretariat

For those interested in using the Inventory, please contact; Director, Climate Change Secretariat

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01st Edition

ACRONYMS

AD	Activity Data
AFOLU	Agriculture, Forestry and Other Land Use
AR	Assessment Report
CBSL	Central Bank of Sri Lanka
CCS	Climate Change Secretariat
CDD	Colombo Development Dialogue
CEB	Ceylon Electricity Board
COP	Conference of the Parties
CPC	Ceylon Petroleum Corporation
CTCN	Climate Technology Centre and Network
DCS	Department of Census and Statistics
DMT	Department of Motor Traffic
EF	Emission Factor
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GWP	Global Warming Potential
GoSL	Government of Sri Lanka
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
MoE	Ministry of Environment
NC	National Communication
NDCs	Nationally Determined Contributions
PTF	Presidential Task Force
RF	Radiative Forcing
SDC	Sustainable Development Council
SDGs	Sustainable Development Goals
SLR	Sri Lanka Railway
SLSEA	Sri Lanka Sustainable Energy Authority
SR	Special Report

TNC	Third National Communication
UN	United Nations
UN-Habitat	United Nations Human Settlements Programme
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly

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PART ONE

BASICS OF GREENHOUSE GAS EMISSION INVENTORIES

SECTION 01: INTRODUCTION

1.1 Greenhouse Gas Emissions and Climate Change

Several chemical compounds found in the atmosphere allow solar radiation to enter the atmosphere and prevent infrared radiation from escaping back to space, which is similar to the phenomenon occurs in greenhouses. These compounds are known as greenhouse gases (GHGs). Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are a few examples. The change in the net (downward minus upward) radiative flux (expressed in W/m^2) at the top of atmosphere is referred to as radiative forcing (RF). A scientific consensus has emerged that increasing concentrations of GHG emissions in the Earth's atmosphere leads to increase in RF that causes the global warming, a gradual increase in average global temperatures.

Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost [1]. Global warming further stresses the ecosystems through other direct and indirect consequences such as salt invasion, fresh water shortages, increased fire threats, spread of some diseases, weed and pest invasions, affects on wildlife and their habitats.

United Nation Framework Convention on Climate Change (UNFCCC) sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. Adopted at the Earth Summit in Rio de Janeiro in 1992 (Rio Summit), UNFCCC has its objective as stabilization of GHGs concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climatic systems. Intergovernmental Panel on Climate Change (IPCC) is the United Nations (UN) body for assessing the science related to climate change. The IPCC prepares comprehensive Assessment Reports (AR) about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

IPCC estimates that human activities have caused approximately 1.0 °C of global warming today above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5 °C between 2030 and 2052, and about 3 °C by the end of this century, if it continues to increase at the current rate. In addition to stresses on ecosystems, the climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. In order to be consistent with global emission pathways with no or limited overshoot of the 1.5 °C goal, global net anthropogenic CO_2 emissions need to decline by about 45%

from the 2010 level by 2030, reaching net zero around 2050. For limiting global warming to below 2 °C, CO_2 emissions need to decrease by about 25% from the 2010 level by 2030 and reach net zero around 2070 [2].

Thus, understanding of the causes, processes, effects and impacts of GHG emissions and climate change is fundamental to the sustainable development of the human society.

1.2 The 2030 Agenda and Climate Action

Climate Action means stepped-up efforts to reduce GHG emissions (mitigation) and strengthen resilience and adaptive capacity to climate-induced impacts (adaptation), as a response to the adverse impacts of global warming and climate change highlighted above. As the climate change impacts are linked to multiple issues related to the all the three dimensions of sustainability: Environment, Society and Economy, the topic of Climate Action has transpired with the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) [3].

The 2030 Agenda and SDGs provide an inclusive approach to transform the world towards sustainable development, addressing multiple development challenges, one of which is the climate change due to emission of GHGs. Although Climate Action represent one SDG (among 17), climate change poses the single biggest threat to sustainable development. As all SDGs are interconnected and indivisible, climate action and socio-economic development can be made mutually enhancing. On the other hand, inadequate climate policies and actions leads to more natural hazards & environment degradation, leading to multiple challenges for socio-economic developments.

1.3 The Paris Agreement and Nationally Determined Contributions

Alongside UN endeavors related to sustainable development, Parties to the UNFCCC continue to adopt decisions, review progress and consider further action on climate change through regular meetings of the Conference of the Parties (COP). At the 21st meeting of the COP (COP21) in 2015, the Paris Agreement on Climate Change was adopted, where every country agreed to the following:

- Work together to limit global warming to well below 2 °C degrees and aim for 1.5 °C,
- Adapt to the impacts of a changing climate, and
- Make resources available to deliver on these aims.

The Paris Agreement requires all countries to bring forward national plans in every five years to set out how much GHGs would be reduced (i.e. emissions reduction targets), which is known as Nationally Determined Contributions (NDC). The year

2020 marked the first of these five-year cycles, and this year the 26th meeting of the COP (COP26) is scheduled to be held in the city of Glasgow, Scotland, between 31st October and 12th November 2021 (delayed by a year due to the COVID-19 pandemic) [4].

Despite the variety of policy efforts and the existence of UNFCCC, the Paris Agreement and NDCs, GHG emissions have grown at a higher rate. The sixth assessment report (AR6) of IPCC published provides new estimates of the chances of crossing the global warming level of 1.5°C in the next decades, and finds that unless there are immediate, rapid and large-scale reductions in GHGs, limiting warming to close to 1.5°C or even 2°C will be beyond reach [5].

Further, a study on latest available NDCs of 164 member countries as at 30 July 2021 highlights that the implementation of all the latest NDCs is not adequate for limiting global warming to below 1.5 °C or even 2 °C. This implies an urgent need for either a significant increase in the level of ambition of NDCs between now and 2030 or a significant overachievement of the latest NDCs, or a combination of both, in order to attain cost-optimal emission levels. If emissions are not reduced by 2030, the countries will need to be substantially reduced thereafter to compensate for the slow start on the path to net zero emissions. In response to above, some member countries have formulated long-term mitigation visions, strategies and targets for up to and beyond 2050 for carbon neutrality [6].

1.4 National Commitments

Sri Lanka ratified the UNFCCC in 1993, and it has an obligation to prepare a National Communication (NC) to the COP convention as a non-annex 1 country party. NC is a report that each Party to UNFCCC prepares periodically in accordance with the guidelines developed and adopted by the COP. Specifically, a NC is a commitment of each Party to provide [7]:

- Information on a national inventory of anthropogenic emissions by sources and removals by sinks of all GHGs,
- General description of steps taken or envisaged to implement the Convention, and
- Any other information that is considered as relevant and important.

Consequent, the Climate Change Secretariat (CCS) was established as the national focal point for the UNFCCC and related activities. Sri Lanka has submitted its first and second NCs in 2000 and 2012, respectively. The third NC (TNC) is in the final stage of completion, which provides the estimates of anthropogenic GHG emissions in Sri Lanka by sources and removals by sinks under several sectors and relevant subsectors for the year 2010. In addition, the GHG emissions are calculated for the time-period extending from the previous inventory year (i.e. 2000) to the current one (i.e. 2010). The key sectors included in TNC are [8]:

- Energy,

- Transport,
- Industrial Processes and Product Use (IPPU),
- Agriculture, Forestry and Other Land Use (AFOLU), and
- Waste.

Sri Lanka has submitted its updated NDCs in September 2021, which include prioritized actions in specific sectors, with estimated GHG reduction targets by 2030 in 06 mitigation and 09 adaptation sectors, as presented in Table 1.1 [9].

Table 1.1: NDC sectors

Category	Sectors			
Mitigation	Electricity	Transport	Industry	
	Waste	Agriculture	Forestry	
Adaptation	Agriculture	Fisheries	Livestock	Biodiversity
	Water	Coastal & Marine	Tourism & Recreation	
	Health	Urban Planning & Human Settlement		

1.5 Cities and GHG Emissions

The major causes of GHG emission and climate change are attributed to economic development of human societies and countries that is characterized by human settlements and urbanization. Urbanization has become a rapidly growing force, as an increasing number of people have begun to move to towns and cities. As today's cities are part of the global environment, their policies, development activities and people have impacts far beyond the city borders [10]. Towns and cities rely on a wide range of resources (including water, energy, food, and raw materials for manufacturing) from outside their geographical boundaries, demands of which that can have significant environmental effects on distant locations. Cities account for 78% of the world's primary energy consumption and create more than 70% of GHG emissions [11]. At the same time, cities are increasingly threatened by the effects of climate change, leading to significant attentions on the topics such as climate-resilience and disaster risk management.

Today, both national governments and municipal authorities recognize the potential for cities to limit the magnitude of climate change through effective mitigation actions. Many cities have already engaged in the challenge and are participating in dedicated international information-sharing and collaboration networks, e.g. the C40 Cities Climate Leadership Group, Local Governments for Sustainability (ICLEI) and Global Covenant of Mayors for Climate and Energy. As the comprehensive and coordinated efforts are essential for Climate Actions that are truly transformative in nature, planning provides a fundamental tool for cities and local government to use when addressing such challenges. They could frame their strategies and programmes, actions into ongoing urban development, and forging the partnerships necessary for effective climate action. GHGI for a city is one basic tool to support such planning [12].

1.6 Local Circumstances

The important role of cities and local governments in climate change subject discussed in the previous section is in general applicable to Sri Lanka. Sri Lanka's urban population is estimated to be between 35 - 45% based on the urban facilities available, indicating the circumstances related to cities prevail in local regions in periurban and rural areas too. In fact, many urban facilities are fast reaching out into many parts of the country, while persuading urban lifestyles and aspirations, which resulting in more adverse impacts on both the local environment and global phenomena such as climate change.

In fact, the emphasis on environment management in cities and human settlements (C&HSs) is apparent in national development policies as well as related sectoral policies and action plans. The National Policy Framework- Vistas of Prosperity and Splendour highlights a policy on developing "Green, Smart, Resilient Cities and Settlements", while National Environment Policy (Draft) and National Environment Action Plan (Draft), that are being updated, include C&HSs as a key thematic area of intervention. These policies, strategies and targets aim at achieving sustainable development, building climate resilience and adopting low carbon technologies to enhance environment soundness.

Further, in accordance with the Sri Lanka Sustainable Development Act No. 19 of 2017, the government mandated all state institutions, including both national and local governments, to prepare Public Service Delivery Strategies to mainstream SDGs, incorporating sustainable development targets relevant to the scope of their assigned subjects. As per this directive, each state institution is required to identify institutional level goals, strategies, programmes and projects and obtain formal approval [13]. This involves a comprehensive assessment of programmes and projects, alongside institutional mandates, priorities, policy/regulatory environment, resources and stakeholders, linking to SDGs. Thus, cities and local government are required to assess Climate Action (SDG13) in broader context of sustainability, which essentially needs collection and assessment data on GHG emissions.

1.7 Accounting for GHG Emissions in Cities

Accounting for GHG emissions for a city requires a clear definition of related system boundaries. The definition of a 'city' poses semantic and technical issues. A unique definition of 'city' does not exist [14], but several definitions representing different perspectives are possible according to the field of knowledge, i.e. urbanism, geography, economy, sociology, etc. Each definition has a different scope, and this has consequences for the determination of the system boundaries and the subsystems to be included. In this study, the cities are recognized by administrative boundaries of Urban Councils and Municipal Councils.

The other more complicate issue in establishing GHGIs for cities it that activities taking place within a city can generate GHG emissions that occur inside the city boundary as well as outside the city boundary. The grid electricity usage in the city in which the grid-commented thermal power plants are located outside the city boundary is one such example. The disposal of municipal solid waste (MSW) generated within the city in a dumpsite outside the city boundary is another example. The transport sector too creates more complexity due to movement of vehicles, people and goods across city boundaries.

SECTION 02: GREENHOUSE GAS INVENTORIES

2.1 An Overview

A GHGI estimates the quantity of GHG emissions and removals associated with sources and activities taking place in a given area during a chosen analysis year. It may also contain supporting data on the locations of the sources of GHG emissions, emission measurements where available, emission factors, capacity, production or activity rates in the various sources, operating conditions, methods of measurement or estimation, etc. A GHGI can be developed at regional, national, sub-national, local or facility levels. Fundamental features of all these GHGIs are the same, while the differences are arisen from the objectives and scope of the assessments. In this manual, the focus is primary on city level GHGIs.

As the contribution of cities on the climate changes as well as impacts of climate change on cities are projected to increase in the future, proper understanding on the related aspects is required, particularly on the qualitative and quantitative characteristics of the emission sources and processes. GHGI is the most effective tool available to cater for this requirement. In fact, GHGI is a critical pre-requisite for policy support and response toward climate actions but has to be supported by strategy development and implementation. Further, effective mitigation and adaptation planning should be evidence-based: grounded in a scientific understanding of climate change when possible (given the constraints faced by cities in obtaining relevant data), and informed by local knowledge. While complying with local requirements, cities are encouraged to use an international reporting methodology based on the GHG protocol standards. These reporting protocols enable the climate benefits of different strategies to be compared in a transparent manner, in a way that permits the contribution of cities globally to be assessed, and paving the way for alignment with national level reporting [12].

2.2 Objectives of GHGIs

In case of cities or local governments, developing a GHGI is the first step to implementing sustainability into their planning and policy-making, and is the basis from which to develop a climate action plan. In addition, there can be a variety of other intentions of the development of GHGIs depending to the particular circumstances and priorities. Following are some examples of the objectives of GHGIs of cities or local governments:

- Inform climate action policy making and planning,`
- Explore GHG mitigation measures,
- Set GHG emission reduction targets,
- Track GHG emissions performance over time,
- Get access to resources to support climate actions,
- Demonstrate accountability and leadership,

- Motivate city community/stakeholder action,
- Recognize GHG emissions performance relative to similar cities,
- Enable aggregation of GHG emissions data across regions and nation,
- Demonstrate compliance with regulations, voluntary agreements, and market standards (where applicable).

2.3 Main Elements of a GHGI

In general, GHGI comprises of several elements covering both parameters and processes. These elements are interconnected systemically with specific order of information flow, as illustrated in Figure 2.1 [15].

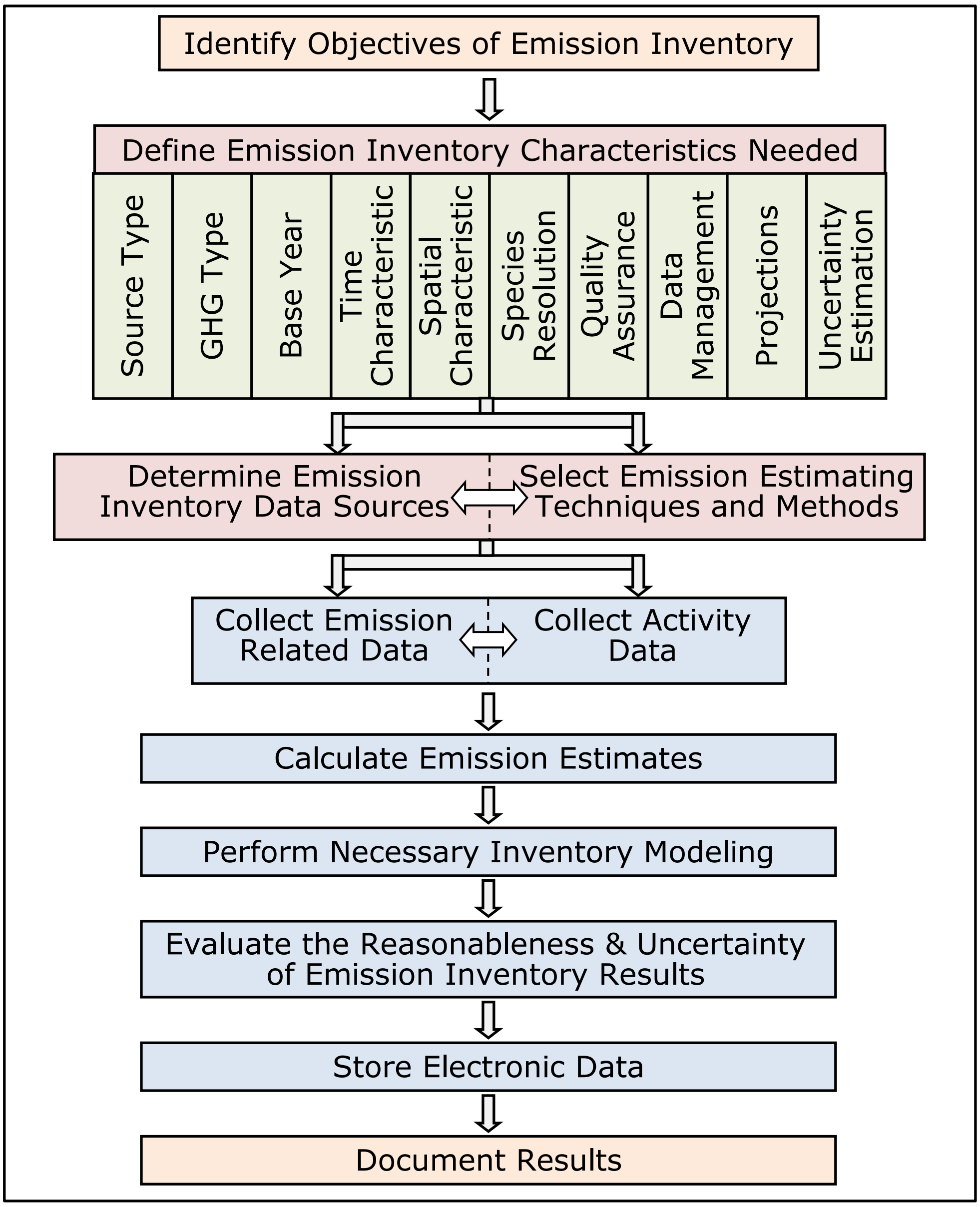


Figure 2.1: The main elements of a GHGI

As illustrated in Figure 2.1, after setting the objective/s (see Section 2.2 above), the characteristics of the key parameters/attributes of GHGI required should be defined. A brief description of each of these parameters is presented below. Details of the other key elements are presented in the subsequent sections.

- **Source Type**

There is a wide range of GHG emission sources and sinks. Here the term source refers to any physical process or activity that releases GHG emissions into the atmosphere. Some examples include vehicle exhaust from combustion of gasoline, furnace exhaust from the combustion of oil, emissions from cook stoves due to combustion of LPG, power plant exhaust from combustion of coal for the production of electricity, emission from waste dumpsite. The term sink refers to a biological system or other natural environment, such as a forest or a body of water that absorbs more carbon dioxide from the atmosphere than it releases (thus resulting removal of GHG).

GHG emissions that are a direct result of human activities or are the result of natural processes that have been affected by human activities are referred to as anthropogenic emissions. Accordingly, emission sources could be broadly categorized as stationary sources and mobile sources.

- Stationary Sources

Stationary source refer to qualitative term used to describe any fixed emitter of GHGs, which can be further divided into point, area and natural sources. In general, the division of emission sources into point and area sources is arbitrary but necessary to allow for the efficient collection of information to support GHGI programmes. Sources identified on an individual facility basis or as a single source are called point sources. Power plants, Refineries and industrial plants are examples of point sources. The emission characteristics of individual facilities vary widely and each facility is examined individually. Data on the activity, seasonal variations, and hours of operation are collected from each facility.

Stationary sources that do not identified individually are called area sources. These represent the emissions from sources that are too numerous and dispersed to efficiently include in a point source inventory. For example, bakeries, service stations and fuel stations are often treated as area sources. Area sources also include the diverse small sources which individually do not emit significant amounts of pollutants but which together make an appreciable contribution to the GHGI. Examples of area sources are residential cooking and use of consumer products.

In addition to human activities, there are significant quantities of GHG emissions (and removal) from natural sources and process. There are two main natural sources commonly considered in GHGIs: Biogenic emissions (e.g. vegetation) and emissions from soil.

- Mobile Sources

Mobile sources consist of on-road motor vehicles and other mobile sources. Usually, mobile sources are a subcategory within the area source category of pollutant emission sources and referred to as line-sources. However, due to their large emissions magnitude and the special considerations required to develop emission estimates, these are addressed separately from area sources. On-road motor vehicles consist of passenger cars, duel-purpose vehicles, lorries, trucks, buses, three wheelers and motorcycles. Emissions from on-road motor vehicles are usually the major portion of a GHGI. Other mobile sources include boats and ships, trains, aircraft, and other diverse set of off-road vehicles. The movement of off-road motor vehicle sources occurs on surfaces other than the public roads and highways. Some of the examples include agricultural, garden and construction equipment, industrial equipment, airport services equipment, light commercial equipment, etc.

GHG emissions are generated from a variety of processes, most common of which is the combustion of fuels and other materials (such as waste). In addition, industrial production processes which chemically or physically transform materials. During these processes, many different GHGs can be produced. In addition, transmission, storage and use of fuels or other substances could lead to fugitive emissions through leakage and evaporation. Another example is fugitive emissions from landfills. Accordingly, emission processes could be categorized as Combustion processes, Fugitive/mechanical processes and Biological processes.

- **GHG Type**

The established purposes of an emissions inventory will determine which pollutants should be included in the inventory. In general, GHGI would focus on CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. In addition, it could also include precursors whose emissions lead to the formation of substances in the atmosphere with a climate change impact (i.e. GHGs). Precursors include SO_2, NOx, non-methane volatile organic compound (NMVOC) and carbon monoxide (CO). More details of GHGs are presented in Section 2.4.

- **Base Year**

The base year of an inventory identifies the year for which emissions are estimated and fixes an inventory's position in time. This provides a benchmark against which previous and subsequent inventories can be compared.

- **Analysis Year**

The single year timeframe for which GHG emissions are being quantified and reported. Typically, the analysis year refers to when the emissions occur, but in some cases it refers to when the activity occurs (e.g., future emissions resulting from disposal of waste in the analysis year). Initially, base year and the analysis year could be the same.

- ### Time Characteristics

There are two main time characteristics that must be considered in every inventory: time period and temporal variability. Time period refers to the length of time represented by the inventory and the emissions will be presented in units of mass of pollutant per inventory time period (e.g. kg CO_2/yr). For many large-scale inventories, the time period will typically be one year. Temporal variability describes the variation of emissions over time. If the emissions are constant over time, then temporal variability is not of much concern. However, most emissions do change over time. Depending upon the inventory requirements, emission variations might need to be described on a seasonal, monthly, daily, hourly (or even shorter time period) basis.

- ### Spatial Characteristics

There are two primary spatial characteristics: inventory domain and spatial resolution. The inventory domain represents the area for which air pollutant sources will be inventoried. Often, the inventory domain follows political, geographical or air quality agency boundaries. Spatial resolution describes how specifically the geographic location of pollution sources must be defined. Basic inventories will sometime provide pollutant totals only for the entire inventory domain. More complex inventories often require a more detailed description of emissions distribution.

- ### Species Resolution

Species resolution refers to disaggregating an inventory pollutant into its individual chemical components or into specific groups. Many inventories will not include detailed species resolution.

- ### Quality Assurance

Quality assurance is an essential element of any emissions inventory, which will help ensure a high quality inventory. Quality assurance should be conducted throughout the development of the inventory. Some of the quality assurance activities include:

- Using a source category checklist, confirming that all necessary sources have been included
- Check sampling results and activity data for "out-fliers" prior to emission calculations
- Confirm that all emission calculations have been performed properly
- Compare inventory results with emissions inventories in similar regions.

- **Data Management**

Another essential emission inventory characteristics is the data management required for the inventory. With the widespread use of computers and increasing inventory data requirements, all inventory data is handled electronically in a workbook, such as worksheet (spreadsheet)-type application or a database application. Worksheets tend to be easier to use, thus selected for the GHGI for Cities, but databases are much more powerful and may be used in the future.

- **Projections**

Projections forecast a base year inventory forward or backward in time. Projections are mainly used to track past and future emission trends due to activity growth and implemented control strategies. Projection methodologies and required data should be established early in the inventory development process.

- **Uncertainty Estimation**

Uncertainly estimates are valuable tool to assess the accuracy of an emission inventory. In general, when uncertainty estimates are made, they are most commonly qualitative in nature. Qualitative estimates may focus on methodologies, activity data, emission-related data, underling assumptions or other components of inventory development. Quantitative uncertainty estimates are unusual, as the derivation can become very statistically complex and requires a large number of assumptions. Although qualitative estimates do not statistically calculate the uncertainty, they are valuable because they point out potential weaknesses in the inventory.

2.4 Greenhouse Gases and Global Warming Potentials

The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The level of impacts of these gases on the global warming differ from each other, and depends primarily on two factors: (i) ability to absorb energy (radiative efficiency), and (ii) duration of existence in the atmosphere (lifetime). In order to have comparisons of the global warming impacts of different gases, the concept of Global Warming Potential (GWP) is used.

GWP is defined as the ratio of RF (degree of warming to the atmosphere) that would result from the emission of one mass-based unit of a given GHG compared to one equivalent unit of carbon dioxide CO_2 over a given period of time. Here, CO_2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long period of time. Table 2.1 presents the GWP values defined by IPCC in its fifth assessment report (AR5) [16]. The GPW values are used to calculate CO_{2e} of the non-CO_2 gases, thus representing GHG emissions in a common unit (e.g. Gg CO_{2e}).

Table 2.1: Global warming potentials of selected GHGs

Species	Chemical formula	Global Warming Potential (100 year time horizon)
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265
HFC-134	$C_2H_2F_4$	1,120
HFC-134a	CH_2FCF_3	1,300
Perfluoromethane (PFC-14)	CF_4	6,630
Perfluoroethane (PFC-116)	C_2F_6	11,100
Sulphur hexafluoride	SF_6	23,500
Nitrogen trifluoride	NF_3	16,100

2.5 Data Collection

Collection of data is a fundamental part of the GHGI development. In most cases, generating data for new source will be limited by the resources available and thus prioritization will be needed. The information required to estimate the activity data could be derived from different methods depending on the data availability and accessibility. Most common methods are:

- Material Balance (raw materials, fuel consumption)
- Source Sampling (direct or indirect) and/or Surveying
- Modeling and/or Extrapolation
- Use of census-based factors and activity Data

Data collection procedures are necessary for finding and processing existing data that are compiled and stored for other statistical uses than the inventory, as well as for generating new data by surveys or measurement campaigns. Following are some potential information sources:

- City or local government level
- Institutional level, for examples Ceylon Electricity Board (CEB) and Sri Lanka Sustainable Energy Authority (SLSEA) for electricity related data, Ceylon Petroleum Corporation (CPC) for fuel oil related data, Department of Motor Traffic (DMT) for vehicle registration related data and Sri Lanka Railway (SLR) for rail related data.
- National level, such as Department of Census and Statistics (DCS)
- Programme/Project level (e.g. CTCN-Kurunegala MC)
- Facility level (e.g. Power Plants or large industry).

The data available in these information sources could be enlist under six distinct categories, in line with the data tier system introduced by DSC for sustainable development indicators, for easy referencing and better traceability as:

- Class 1: Data are already compiled by the National Statistical System (i.e. DCS) through ongoing censuses and surveys and administrative records.
- Class 2: Data to be compiled by the National Statistical System (i.e. DCS) adding new modules into ongoing censuses and surveys or through new surveys and special studies.
- Class 3: Data are available through other institutions of the National Statistical System or specific agencies (e.g. DCS, CEB, SLSEA, CPC).
- Class 4: Data to be compiled by other institutions of the National Statistical System or specific agencies (e.g. DCS, CEB, SLSEA, CPC)
- Class 5: Data corresponding to regional or global levels, such as IPCC
- Class 6: Data available with other agencies, facilities and programmes (e.g. local government agencies).

Further, the data required for the emission estimates could be obtained from two approaches:

- Top-down approach: Estimation of emissions using available generic data.
- Bottom-up approach: Estimation of emissions using specific data.

Though less accurate, use of generic data is a common practice as there are limited data availability at the city level. However, where possible, use of more accurate data that represent the local circumstances is desired to enhance the integrity of the GHGI. IPCC recommends three Tier system (Tier 1, 2 and 3) to rate the reliability of GHG estimates [17]. Each Tier denotes the level of complexity involved in the estimates. Increase in the tier number denote more accurate and more specific information that results in more refined estimates. However, higher tiers need more intensive efforts and resources to produce the data. The three tiers introduced by IPCC are:

- Tier 1: Reflects default activity data, e.g. readily available energy statistics, production statistics and corresponding emission factors for typical/familiar process conditions, with the default emission factors and other parameters provided by the IPCC.
- Tier 2: Generally uses the same methodological approach as Tier 1 but applies process conditions, technological details emission factors and other parameters that are specific to the country or locality.
- Tier 3: Most detailed method and can use facility level data, including sophisticated models. These methods can provide estimates of greater certainty than lower tiers.

Here Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate. Tier 1 methods for all categories are designed to use readily available national or international statistics in combination with the provided default emission factors and additional parameters that are provided, and therefore should be feasible for all cities in preparing GHGIs. Tier 1 and Tier 2 methods estimate the emissions by multiplying the activity data with an emission factor, as given in Section 3.6 below.

2.6 Estimation Methodology

The most common simple methodological approach used in GHGIs to estimate emission from is to combine information on the extent to which a human activity takes place (which is called activity data) with coefficients which quantify the emissions or removals per unit activity (which is called emission factors). For example, estimating CO_2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity consumption by the emission factor (kg CO_2/kWh) for electricity, which will depend on the technology and type of fuel used to generate the electricity. In transport, CO_2 emissions from the use of fuel in a vehicle involves multiplying data on volume (m^3) of fuel consumption by energy density of the fuel (MJ/m^3) and the emission factor (kg CO_2/MJ) for fuel, which will depend on the vehicle technology/category and type of fuel used.

The basic equations for the estimation of total GHG emission in a city could be represented by the following set of equations:

- GHG emissions = Σ[Activity data × Emission factor]
- GHG removals = Σ[Activity data × Removal factor]
- Net GHG fluxes = GHG emissions - GHG Removals

Here, the summation (Σ) denotes the contribution from multiple sources and activities in the region considered in the assessment. Note that the above expressions are generic in form and depending on the type of the source and the process, the activity data may depend on more than one parameter.

PART TWO

DEVELOPMENT OF GREENHOUSE GAS EMISSION INVENTORIES FOR CITIES

SECTION 03: METHODOLOGY

3.1 Guiding Principles of GHGIs for Cities

The methodology for the development of GHGIs for cities is derived with a set of guiding principles to ensure relevance, completeness, consistency, transparency, accuracy and measurability, with particular emphasis on the GHGI Manual and Workbook (Spreadsheet). The key guiding principles are [18]:

- *Transparency* - Activity data, emission sources, emission factors, and accounting methodologies should be adequately documented and disclosed to enable verification. The information should be sufficient to enable individuals outside of the inventory process to use the same source data and derive the same results. All exclusions need to be clearly identified and justified.
- *Relevance* - The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption from within the city's geopolitical boundary. The inventory shall also serve the decision-making need of the local government, and take into consideration relevant local and national regulations.
- *Accuracy* - The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient to give decision makers and the public reasonable assurance of the integrity of the reported information. City or a local government should reduce uncertainties in the quantification process to the extent that it is possible and practical.
- *Completeness* - All emissions sources within the inventory boundary shall be accounted for. Any exclusion of emission sources shall be justified and clearly explained.
- *Consistency* - Emissions calculations shall be consistent in approach, boundary, and methodology. Consistent methodologies for calculating GHG emissions will enable meaningful trend analysis over time, documentation of reductions, and comparisons between cities and local governments.
- *Comparability* - The GHGI is reported in a way that allows it to be compared with other inventories from other cities and local governments. This should be reflected in appropriate choice of emissions or removals categories and in the use of the same reporting guidelines as that of the other cities and local governments.

3.2 Overall Methodical Framework

As the GHGI comprises of several key elements with interdependence characters, the development process itself is complicate, and demands for strategic approach. One way to get on with this status is to breakdown the whole process into distinct but interconnected stages. Such a strategic approach represents a step-wise circular model of continuous learning and improvement process, which results in adaptive responses to uncertainties and evolvement of values that can also applied to decision making. The overall framework of the proposed methodology is presented in Figure 3.1.

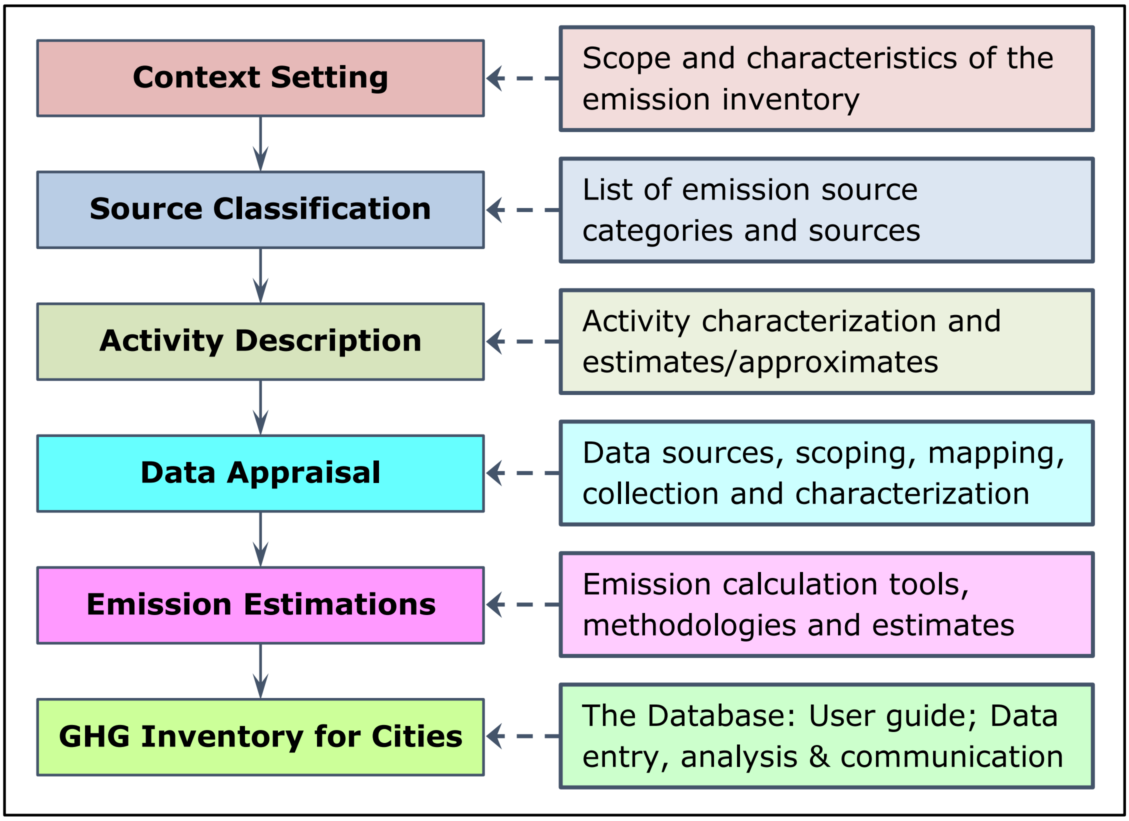


Figure 3.1: Overall Framework for the development of GHGIs for cities

3.3 Key Steps

Within the above framework, more descriptive tasks could be identified to facilitate the development of GHGI for cities. These tasks could be categorized as a set of key steps of the formulation and operation processed of GHGI. These key steps are:

Step 1. Setting of objectives and end-user requirements of the inventory,

Step 2. Identification of the geographical inventory area & definition of source/activity/ emission boundary,

Step 3. Consideration of all important sources & GHGs,

Step 4. Compatibility of defined source categories with available source and emission data,

Step 5. Detailed source categories to facilitate mitigation strategy projections,

Step 6. Selection of an inventory data handling system (e.g. Microsoft Excel),

Step 7. Definition of data tier system & reporting formats,

Step 8. Selection and documentation of quality assurance procedures, Step 9. Identification of logistical needs for data collection,

Step 10. Identification of existing emissions estimates,

Step 11. Determination of the temporal basis of emissions,

Step 12. Determination of most appropriate & alternative data collection methods,

Step 13. Selection of the inventory base year,

Step 14. Compilation of the frequency of emissions,

Step 15. Adjustment of seasonal variations of emissions,

Step 16. Decisions on emissions projections and projection period, and

Step 17. Resolution on data sharing & communication.

3.4 Categorization of Emission Sources and Sinks

As there is a wide variety of GHG emission sources and processes, the formulation of GHGI for cities demands for methodical grouping of sources (and sinks) under sectors/sub-sectors to estimate the emissions and removals. Table 3.1 presents such categorization to identify relevant sources (adapted from [17], [19]).

Table 3.1: Main categories of emissions by sources and removals by sinks

Sector	Subsector
Stationary Energy (Both combustion and fugitive emissions from fuel)	Residential building
	Commercial and institutional building and facilities
	Manufacturing industries and construction
	Energy industries (Power Plants)
	Agriculture, forestry, and fishing activities
	Fugitive emissions from oil and natural gas systems
Transportation	On-road
	Off-road
	Railways
	Waterborne navigation
	Employee/Community Commute
	Aviation
Industrial Processes & Product Use (IPPU)	Industrial processes (Mineral, Chemical, Metal, etc.)
	Product use
Waste	Solid waste disposal
	Biological treatment of waste
	Incineration and Open burning
	Wastewater treatment and discharge
Agriculture, Forestry and Other Land Use (AFOLU)	Livestock
	Land (Forest land, Copland, Grassland, Wetlands, etc.)
	Aggregate sources & non-CO2 emission sources on land

3.5 Scope of GHG Emissions in Cities

As briefed in Section 1.7, accounting for GHG emissions for a city is a fundamental requirement of GHGI. The geographical boundary is relatively simple as the cities are recognized by administrative boundaries of Urban Councils and Municipal Councils. However, the boundary of the GHG emissions is more difficult to define as activities taking place within a city can generate GHG emissions that occur inside the city boundary and vice versa. Therefore, it is fundamental to establish a clear definition for the emission boundary by considering the related emission sources to account GHG emissions in cities. In this study, GHG emission boundary for GHGI for cities is defined in relation to geographical boundary in three scope of activities/sources as [19]:

- Scope 1: GHG emissions from sources located within the city boundary, except electricity generation facilities catering for the users outside the city boundary;
- Scope 2: GHG emissions occurring outside the city boundary as a consequence of the use of grid-supplied electricity or other energy carriers within the city boundary; and
- Scope 3: All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary (E.g. Waste, Transport, Water).

Figure 3.2 illustrates the above three scopes in relation to the geographical boundary.

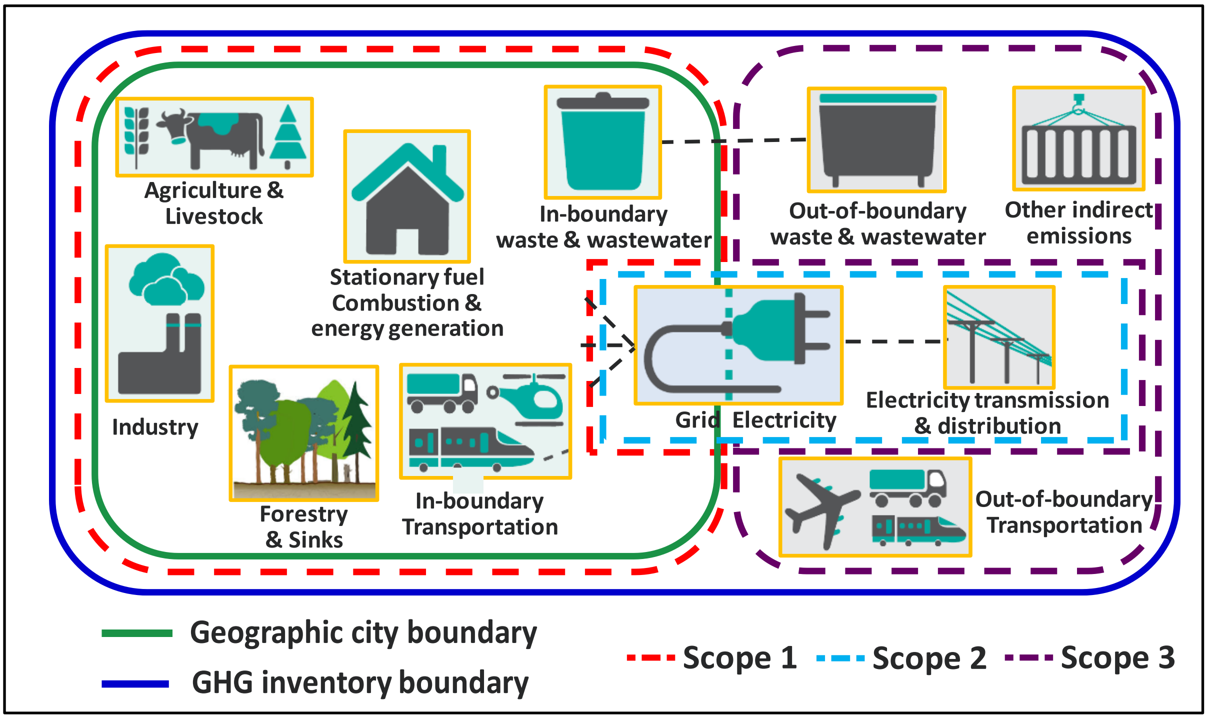


Figure 3.2: Scopes of emission boundaries of GHGIs for cities

3.6 Key Categories of Sources and Sinks

Based on the information provided in Section 3.4 on the categories of GHG emission sources and sinks, and the scope of the accounting for GHG emission in cities presented in Section 3.5, the local circumstances and priorities can be taken into account to identify the sources and sinks to be in the GHGIs for cities. A summary of the source categories. Sectors/sub-sectors are presented in Table 3.2 (see Figure 3.2 too).

Table 3.2: Key sectors of GHG emissions

<table>
<tr><th>Scope</th><th colspan="3">Key Sector</th></tr>
<tr><td rowspan="3">Scope 1</td><td>Stationary energy</td><td colspan="2">In-boundary transportation</td></tr>
<tr><td>Industrial processes</td><td colspan="2">In-boundary waste & wastewater</td></tr>
<tr><td>Agriculture & Livestock</td><td colspan="2">Forestry & Sinks</td></tr>
<tr><td>Scope 2</td><td>Grid electricity</td><td colspan="2">Out-of-boundary transportation</td></tr>
<tr><td rowspan="2">Scope 3</td><td>Water</td><td colspan="2">Out-of-boundary waste & wastewater</td></tr>
<tr><td colspan="2">Electricity transmission & distribution</td><td>Other indirect sources</td></tr>
</table>

Further, within the assessment area of the city, there could be thousands of emission sources and sinks contributing to GHG emissions and removals. However, estimation of all these is not practical due to limitations in information and resources. Further, as emissions and removals of many source and sink categories may not be significant compared with some others categories. Thus prioritization of the categories having significant influence on the total inventory of GHGs in the city in absolute terms or trends becomes a necessity. The prioritized ones are referred to as the key categories, which include both sources and sinks. The assessment and prioritization should also consider the availability and accessibility of the required data on the characteristics of the sources and sinks that are required for the estimations. The categories having insufficient data are usually not included in the GHGI. However, cities should make every efforts to fill the data gaps of the categories deemed to have significant contributions.

Assessing the key categories helps the city to focus effort and resources on the sectors that contribute most to the overall GHGI and so helps to ensure that the best possible inventory is compiled for the available resources. Key categories should be the priority for cities during GHGI resource allocation for data collection, compilation, quality assurance/quality control and reporting. Table 3.3 and Table 3.4 provide indicative description of sectors/sub-sectors of GHG sources/sinks, together with applicable GHGs that could be included in GHGI for cities.

Table 3.3: GHGI sources and sinks of main GHGs and GHG precursors

Greenhouse gas source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)	NMVOCs (Gg)	SO_x (Gg)
Total national emissions and removals	X	X	X	X	X	X	X	X
1. Energy	X	X	X	X	X	X	X	X
A. Fuel combustion (sectoral approach)	X		X	X	X	X	X	X
1. Energy industries	X		X	X	X	X	X	X
2. Manufacturing industries and construction	X		X	X	X	X	X	X
3. Transport	X		X	X	X	X	X	X
4. Other sectors	X		X	X	X	X	X	X
5. Other (please specify)	X		X	X	X	X	X	X
B. Fugitive emissions from fuels	X		X		X	X	X	X
1. Solid fuels			X		X	X	X	X
2. Oil and natural gas			X		X	X	X	X
2. Industrial processes	X	X	X	X	X	X	X	X
A. Mineral products	X				X	X	X	X
B. Chemical industry	X		X	X	X	X	X	X
C. Metal production	X		X	X	X	X	X	X
D. Other production	X				X	X	X	X
E. Production of halocarbons and sulphur hexafluoride								
F. Consumption of halocarbons and sulphur hexafluoride								
G. Other (please specify)	X		X	X	X	X	X	X
3. Solvent and other product use	X			X			X	
4. Agriculture			X	X	X	X	X	X
A. Enteric fermentation			X					
B. Manure management			X	X			X	
C. Rice cultivation			X				X	
D. Agricultural soils			X	X			X	
E. Prescribed burning of savannahs			X	X	X	X	X	
F. Field burning of agricultural residues			X	X	X	X	X	
G. Other (please specify)			X	X	X	X	X	
5. Land-use change and forestry	X[b]	X[b]	X	X	X	X	X	X
A. Changes in forest and other woody biomass stocks	X[b]	X[b]						
B. Forest and grassland conversion	X	X	X	X	X	X		
C. Abandonment of managed lands		X						
D. CO_2 emissions and removals from soil	X[b]	X[b]						
E. Other (please specify)	X	X	X	X	X	X		
6. Waste			X	X	X	X	X	X
A. Solid waste disposal on land			X		X		X	
B. Waste-water handling			X	X	X	X	X	
C. Waste incineration					X	X	X	X
D. Other (please specify)			X	X	X	X	X	X
7. Other (please specify)	X	X	X	X	X	X	X	X
Memo items								
International bunkers	X		X	X	X	X	X	X
Aviation	X		X	X	X	X	X	X
Marine	X		X	X	X	X	X	X
CO_2 emissions from biomass	X							

Table 3.4: GHGI sources of HFCs, PFCs and SF6

Greenhouse gas source and sink categories	HFCs[a,b] (Gg)			PFCs[a,b] (Gg)			SF_6[a] (Gg)
	HFC-23	HFC-134	Other (to be added)	CF_4	C_2F_6	Other (to be added)	
Total national emissions and removals	X	X	X	X	X	X	X
1. Energy							
A. Fuel combustion (sectoral approach)							
1. Energy industries							
2. Manufacturing industries and construction							
3. Transport							
4. Other sectors							
5. Other (please specify)							
B. Fugitive emissions from fuels							
1. Solid fuels							
2. Oil and natural gas							
2. Industrial processes	X	X	X	X	X	X	X
A. Mineral products							
B. Chemical industry							
C. Metal production	X	X	X	X	X	X	X
D. Other production							
E. Production of halocarbons and sulphur hexafluoride	X	X	X	X	X	X	X
F. Consumption of halocarbons and sulphur hexafluoride	X	X	X	X	X	X	X
G. Other (please specify)							
3. Solvent and other product use							
4. Agriculture							
A. Enteric fermentation							
B. Manure management							
C. Rice cultivation							
D. Agricultural soils							
E. Prescribed burning of savannahs							
F. Field burning of agricultural residues							
G. Other (please specify)							
5. Land-use change and forestry							
A. Changes in forest and other woody biomass stocks							
B. Forest and grassland conversion							
C. Abandonment of managed lands							
D. CO2 emissions and removals from soil							
E. Other (please specify)							
6. Waste							
A. Solid waste disposal on land							
B. Waste-water handling							
C. Waste incineration							
D. Other (please specify)							
7. Other (please specify)	X	X	X	X	X	X	X
Memo items							
International bunkers							
Aviation							
Marine							
CO_2 emissions from biomass							

3.7 Data Collection in GHGIs for Cities

Data collection procedures are necessary for finding and processing existing data, (i.e., data that are compiled and stored for other statistical uses than the inventory), as well as for generating new data by surveys or measurement campaigns. Other activities include maintaining data flows, improving estimates, generating estimates for new categories and/or replacing existing data sources when those currently used are no longer available. In general, cities could follow the data collection procedures, the tier system and classes provided in Section 2.5 to gather the required data for the identified and prioritized emission sources and sinks.

In addition to identifying the method used to calculate emissions given above, cities shall also evaluate the quality of both the activity data and the emission factors used, highlighting the degree to which data reflect the geographical location of the activity, the assessment boundary and emission source, and whether data have been obtained from reliable and verifiable sources.

The methodological principles of data collection that underpin good practice are the following:

- Focus on the collection of data needed to improve estimates of key categories which are the largest, have the greatest potential to change, or have the greatest uncertainty.
- Choose data collection procedures that iteratively improve the quality of the inventory in line with the data quality objectives.
- Put in place data collection activities (resource prioritization, planning, implementation, documentation etc.) that lead to continuous improvement of the data sets used in the inventory.
- Collect data/information at a level of detail appropriate to the method used.
- Review data collection activities and methodological needs on a regular basis, to guide progressive, and efficient, inventory improvement.
- Introduce agreements with data suppliers to support consistent and continuing information flows.

3.8 Data Availability

Data collection is an integral part of developing and updating a GHGI. This includes gathering existing data, generating new data, and adapting data for inventory use. The data collection activities is usually commenced with an initial screening of available data sources. This will be an iterative process to improve the quality of data used and should be driven by two primary considerations:

- Data should be from reliable and robust sources; and
- Data should be time- and geographically-specific to the inventory boundaries, and technology-specific to the activity being measured.

As presented in Section 2.5, the required activity data and emission factors can be gathered from a variety of sources. Yet, it is important to make sure that the data gathered is representative and reliable, thus needs to sets out methodological principles of data collection. Following are such principle that underpin good practice [19]:

- Establish collection processes that lead to continuous improvement of the data sets used in the inventory (resource prioritization, planning, implementation, documentation, etc.)
- Prioritize improvements on the collection of data needed to improve estimates of key categories which are the largest, have the greatest potential to change, or have the greatest uncertainty
- Review data collection activities and methodological needs on a regular basis to guide progressive, and efficient, inventory improvement
- Work with data suppliers to support consistent and continuing information flows

Assessment of the availability of data for the estimation of GHG emissions is a fundamental requirement to identify the sources to be included in GHGIs, under each of the three scope defined in Section 3.5. As there would be data gaps in the estimation and presentation of the GHG emission results, it is a good practice to indicate why the data is lacking through the use of notation keys. In fact, a GHG inventory that lacks proper representation of all emissions, either through quantification or the use of notation keys, does not comply with the completeness principle presented in Section 3.1. Notation keys are a clear, simple and standardized way to show that data has not been reported and why it has not been reported. Table 3.5 presents typical notation keys used in GHGIs.

Table 3.5: Notation keys are used in GHGIs

Notation Key	Definition	Explanation
NE	Not Estimated	Emissions and/or removal occur but have not been estimated or reported (Justification for exclusion shall be noted in the explanation).
NO	Not Occurring	An activity or process does not occur within the city.
IE	Included Elsewhere	Emissions and/or removal for this activity are estimated and presented in another category of the inventory (That category shall be noted in the explanation).
C	Confidential	Emissions and/or removal which could lead to the disclosure of confidential information and can therefore not be reported.
NA	Not applicable	The activity or category exists but relevant emissions and removals are considered never to occur. Such cells are normally shaded in the reporting tables.

3.9 Data Requirement

Once the emission sources and sinks have been identified, the GHG emission estimates need two categories of data: the activity data and emission factors. In case of emission factors, the majority of data will be based on the default values given in IPCC guidelines (2006 and 2019). In some cases, locally appropriate quantities could be used, whenever such data exists. Grid emission factors, fuel properties and composition of waste are some examples. The activity data is primarily based on the information relevant to the city, where some estimates are performed with supplementary information of the relevant national average values due to lack of specific data at the city level. Table 3.6 to Table 3.8 presents the data requirement for the GHGI for cities, for Scope 1 to Scope 3, respectively, under different sectors and sub-sectors/sources.

Table 3.6: Scope 1 data requirement in GHGIs for cities

Sector	Sub-sector	Data type	Principal data sources
Stationary energy	Domestic Commercial & Institutions Industry	Fuel types (LPG, Kerosene, Diesel, Furnace oil, Coal), Fuel consumption, Crude oil imports and petroleum products production.	National energy statistics, National, energy balance, Refinery product balance, National industry census, Fuel sales data, Industry survey data
	Fugitive emissions	Oil refinery data (quantity), Refined products distribution by fuel and quantity	National petroleum statistics, National energy balance, Oil sales data.
Transport (in-bound)	On-road	Fuel types, Fuel consumption, Number of registered vehicles (revenue licenses), Vehicle types, Active vehicle fleet characteristics (passenger-km, ton-km) and fuel economy (l/km)	Vehicle registration database, Revenue licensing data, National, energy balance, Refinery product balance, Petroleum product sales data, Vehicle emission testing (VET) database. Expert judgements.
	Off-road	Fuel types (Gasoline, Diesel), Fuel consumption, Number of registered vehicles (revenue licenses), Vehicle types, Active vehicle fleet characteristics	Vehicle registration database, National, energy balance, Refinery product balance, Petroleum product sales data, Expert judgements.

Table 3.6: Scope 1 data requirement in GHGIs for cities (Cont…)

Sector	Sub-sector	Data type	Principal data sources
Transport (in-bound)	Rail	Fuel types (Diesel), Fuel consumption, Number of trains, Travel distance, No. of passengers, Passenger-km, Ton-km and fuel economy.	National rail statistics, Train passenger ticketing data, Expert judgements.
Waste (In-bound)	Solid waste disposal	Population, Waste generation, Waste collection, Means of disposals and their various percentages, Waste compositions, Waste quantities at dumpsites within the city (daily inputs, accumulated), Conditions of dumpsites.	Population census reports, National study reports, Local government/City survey data, Studies of dumpsites, Expert judgements.
	Incineration	Fraction of waste incinerated/amounts within the city, Technologies, Number of plants, Composition of waste.	Local government/City survey data, National reports, Private waste management companies, Technology suppliers
	Open burning	Population, Proportion of population burning waste, Fraction of waste burnt, Fraction of waste burnt at dump sites within the city, Composition of waste	Population census reports, Local government/City survey data, National reports, Expert judgements
	Biological treatment of waste	Fraction of waste composted or digested (biogas)/amounts within the city, Technologies (Composting, Anaerobic digestion), Number of plants, Composition of waste.	Local government/City survey data, Private waste management companies, Technology suppliers
	Wastewater treatment and discharge - Domestic	Population, Wastewater generation, Fraction of wastewater treated within the city, Wastewater treatment systems and their various percentages, Protein consumption, GDP/capita	Population census reports, National study reports, Local government/City survey data.

Table 3.6: Scope 1 data requirement in GHGIs for cities (Cont…)

Sector	Sub-sector	Data type	Principal data sources
Waste (In-bound)	Wastewater treatment and discharge - Industry	Industrial coverage, Total Industry product quantity of wastewater generated Type of wastewater treatment/ discharge system	Industry census reports, National study reports, Local government/City survey data, Expert judgements
Industrial processes and Product use	Mineral	Type of industry, Processes/ Technologies, Production quantities.	Industry census reports, Industrial data from facilities, Fuel sales data, Expert judgements
	Chemical		
	Metal		
	Other		
	Non-Energy Products	Amount of non-energy use of diesel and kerosene	
Agriculture	Rice	Annual rice production areas, Proportions of annual rice production area under rain fed, irrigated systems	Agriculture facts and figures, Land-use maps, Land-use change maps.
	Cropland	Areas of cultivation, Crop production, Urea & NPK consumptions, Land-use and land-use change patterns, Climate zones, Soil classification	Agriculture facts and figures, Fertilizer sales data, Land-use-maps, Land-use-change maps, Ecological zone maps, Expert judgements
	Agro-residue burning	Generation of agro-residues, Fraction of burning, Areas affected by fire in cropland.	Agriculture facts and figures, Study reports, Expert judgements
Livestock	Enteric Fermentation & Manure Management	Livestock species and categories. Annual population, Fractions of manure, Management practices	Livestock facts and figures, Industry censes.
Forests & Sinks	Forest land	Land-use and land-use change patterns, Industrial round wood production, Fuel wood production, Climate zones, Soil classification, Areas affected by fire	Forestry facts and figures, Land-use-maps, Land-use-change maps, Ecological zone maps, Timber and fuel wood industry data, Expert judgements.

Table 3.6: Scope 1 data requirement in GHGIs for cities (Cont…)

Sector	Sub-sector	Data type	Principal data sources
Forests & Sinks	Grassland Wetlands	Land-use and land-use change patterns, Climate zones, Soil classification	Land-use-maps, Land-use-change maps, Ecological zone maps, Expert judgements.

Table 3.7: Scope 2 data requirement in GHGIs for cities

Sector	Sub-sector	Data type	Principal data sources
Grid Electricity	Residential Commercial Industry Religious Street lights	Electricity consumer categories; Electricity consumption data, Grid emission factors	National energy/ electricity balance, Electricity sector statistics, Electricity sales data
	Solar PV	No. of plants, Capacities, Electricity generation data	Electricity sector statistics, Renewable energy sector statistics, Technology suppliers
Water	Drinking water Irrigation water	Drinking & Irrigation water sources (out-of-boundary) and consumption	Water usage statistics, Water irrigation statistics

Table 3.8: Scope 3 data requirement in GHGIs for cities

Sector	Sub-sector	Data type	Principal data sources
Transport (Out-of-boundary)	On-road	Employee/Commuter population, Mode of road transport, Travel distances	Vehicle registration database, Revenue licensing data, Vehicle Emission testing (VET) database, Expert judgements.
	Rail	Employee/Commuter population, Travel distances	National rail statistics, Train passenger ticketing data, Expert judgements.
Waste (Out-of-boundary)	Solid waste disposal	Waste quantities managed in dumpsites outside the city (daily inputs, accumulated), Conditions of dumpsites.	Local government/City survey data, Studies of dumpsites, Expert judgements.

Table 3.8: Scope 3 data requirement in GHGIs for cities (Cont…)

Sector	Sub-sector	Data type	Principal data sources
Waste (Out-of-boundary)	Incineration	Amounts incinerated outside the city, Technologies, Number of plants, Composition of waste.	Local government/ City survey data, Private waste management companies, Technology suppliers
	Open burning	Amount/Fraction of waste burnt at dump sites outside the city, Composition of waste	Local government/City survey data, National reports, Expert judgements
	Biological treatment of waste	Fraction of waste composted or digested (biogas)/amounts outside the city, Technologies (Composting, Anaerobic digestion), Number of plants, Composition of waste.	Local government/City survey data, Private waste management companies, Technology suppliers
	Wastewater treatment and discharge	Wastewater generation, Fraction of wastewater treated outside the city, Wastewater treatment systems and their various percentages.	National study reports, Local government/City survey data.
Electricity	Transmission & distribution	Transmission & distribution loss factor, Total electricity consumed.	National grid electricity data.

SECTION 04: THE WORKBOOK OF THE GHGI

4.1 An Overview

In line with the methodology presented in Section 3, the Workbook for data management of the GHGIs for cities is formulated in the Microsoft Excel spreadsheet system. The main sections of the Workbook comprised of specific and dedicated sections for clarity, while ensuring the entirety through relevant interconnectivity and interdependency. These sections are administered through a set of worksheets for data entry and analysis, while providing basic guidance for the data management staff of a city. This section of the Manual (Section 4) provides details of all the worksheets and further guidance for the responsible staff to complete the Workbook and operationalize its GHGI, while facilitating other stakeholders to support the effective engagement with the inventory development and implementation. Note that this section should be perused and pursued together with Section 3. It is intended that the material presented in the Workbook and the Manual be used as a resource document for capacity building as well.

4.2 General Structure of the Workbook

The set of worksheets of the Workbook of GHGIs for Cities is categorized under three groups as Front Matter (4 worksheets), The Core (14 worksheets), and Back Matter (2 worksheets), as illustrated in Figure 4.1. The Frontal Matter and Back Matter provide basic information of the GHGIs for Cities, instructions and other data/information. The Core include worksheets for data entry and presentation of results of the GHG emission estimates in number of categorizations and the total.

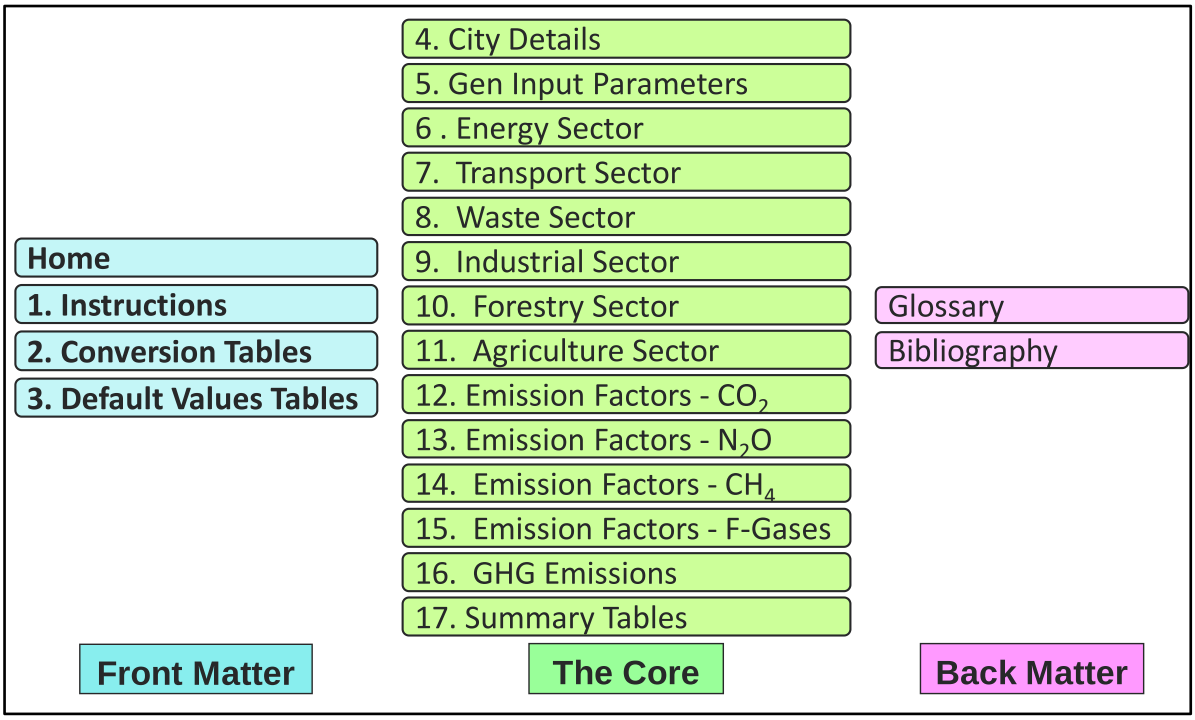


Figure 4.1: Content of the GHGI

The general appearance of each worksheet is presented in Figure 4.2. It contains four main fields: (i) The Main Menu on the left-most column, (ii) Header on the top row, (iii) Footer at the bottom row, and (iv) The central field for the main content of the spreadsheet.

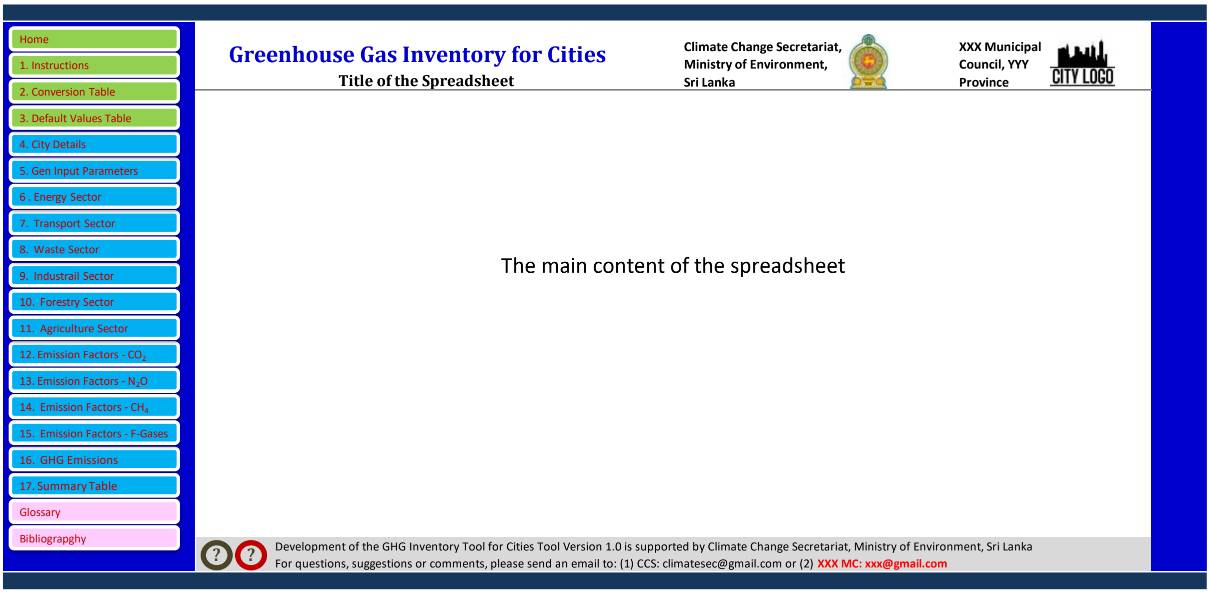


Figure 4.2: General outlook of the worksheets

➔ The Main Menu allows the user to navigate the different areas of the workbook (i.e. any one of the other nineteen worksheets) by clicking on the button with relevant title.

It is also possible to move between worksheets using the sheet tabs at the bottom of the workbook.

➔ The header includes title of the workbook (Greenhouse Gas Inventory for Cities), title of the spreadsheet, the focal point of the Ministry of Environment (Climate Change Secretariat - CCS), the city or local government region that need to be filled with the logo (if any) by the data entry operator.

XXX Municipal Council, YYY Province	CITY LOGO

➔ The footer includes the version of the GHGI tool and the email address of the CCS and the email address of the contact point of the city or local government that needs to be completed by the data entry operator. Further, two buttons with "?" mark having hyperlink to the email of the each entity are also provided for easy connectivity in case further information or assistance is required.

? CCS: climatesec@gmail.com	? XXX MC: xxx@gmail.com

➔ Central field includes content of the worksheet, covering general information and guidance, data/text fields (both uneditable and data or text entry fields).

For easy referencing and usage of the workbook, the cells in the central field use following colour code:

Colour code for Cells		
	Light green:	Numerical or text data entry
	Light blue:	Option selection (dropdown data entry field)
	Light yellow:	Data that cannot edit or should not be edited as they are auto calculated values
	Light gray:	Cells that should not be edited as they are fixed or not relevant for the selected options.

4.3 Instruction for Specific Worksheets

4.3.1 Outline

The front matter contains the following four worksheets:

- Home
- 1. Instructions
- 2. Conversion Tables
- 3. Default Values Tables.

These worksheets intend to provide guidance and basic data/information for the data entry operators to complete the GHGI workbook. The cells in these worksheets are fixed and the data entry operators are not supposed to edit. The details of each of the worksheets are provided in the following sub-sections.

4.3.2 Home worksheet

This worksheet introduces GHGI, its objectives and scope together with GHG emission estimation methodology and GHGs included in the inventory and GWPs, as presented below:

INTRODUCTION	The building of baselines for greenhouse gas (GHG) emissions and maintaining greenhouse gas inventories (GHGI) for cities, leading to national and global level inventories, will assist nations to track their emission levels and employ strategies and actions to reduce emissions. City level GHGI will also support data/information management, with links to provincial and national level data management networks. Furthermore, when cities develop their own GHGI, the information generated could be used to monitor and evaluate outputs, outcomes and impacts of development programmes/projects. This, in turn, provides

	inputs for employing rational decision-making tools for implementation of projects and programmes in the future.

OBJECTIVE	The purpose of this tool is to enable any city to record and estimate their GHG emissions and maintain own GHGI, while communicating the results for knowledge management.

SCOPE	The scope of the city GHG inventory, defined for reporting its contribution includes three main components: (1) GHG emissions from sources located within the city boundary; (2) GHG emissions occurring as a consequence of the use of grid-supplied electricity or other energy carriers within the city boundary; and (3) All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

➔ Refer Section 3.5 and Figure 3.2 for more details and clarity on the scope of the GHG emission of the city/local government.

➔ City boundary: The geographical boundary that determine the operations owned or controlled by the reporting entity such as city or local government.

➔ Emission boundary: GHG emission accounting and reporting boundaries for the reporting entity such as city or local government.

ESTIMATION METHODOLOGY	**GHG emissions = Σ [Activity data × Emission factor]**
	GHG removals = Σ [Activity data × Removal factor]
	Net GHG fluxes = GHG emissions - GHG Removals

➔ Refer Section 2.6 for more details on the GHG emission methodology.

➔ Activity refers to a practice or ensemble of practices that take place on a demarcated area over a given period of time that result in the creation of GHG emissions either directly or indirectly.

Examples of Direct and Indirect GHG Emissions	
Direct Emissions	**Indirect Emissions**
Use of household appliances such as LPG or kerosene cookstove, furnaces	Electricity created via combustion of fossil fuels at a power plant

Use with vehicles internal combustion engines than burn of petroleum fuel such as diesel or gasoline	Consumption of goods and services whose production, transport and/or disposal resulted in creation of GHG emissions directly or indirectly
Open burning of polythene or plastics	

➔ Activity data refers to the magnitude of a human activity resulting in GHG emissions or removals during a given period of time.

Examples of Activity Data		
Fuel or energy use	Waste generation	Land area
Input material to a process	km travel by a vehicle	Management system
Lime & fertilizer use	Number of vehicles	Electricity use

➔ *Emission Factor (EF)*: A unique value for determining an amount of a GHG *emitted* on a per unit activity basis (Refer Section 3.9).

Examples of GHG Emission Factors (EFs)
Metric tons of CO_2 emitted per GJ of coal combusted
g of CO_2 emitted per km of vehicle travel
Metric tons of CO_2 emitted per kWh of electricity consumed
kg of N_2O emitted per cubic meter of furnace oil consumed
kg of CH_4 emitted per person per year due to domestic waste water
Metric tons of CO_2 emitted per metric tons of waste burned

➔ *Removal Factor (RF)*: A unique value for determining an amount of GHG removed on a per unit activity basis.

Examples of GHG Removal Factors (RFs)
Metric tons of CO_2 removed per ha of land area per year
kg of CO_2 removed per tree per year

Greenhouse Gases (GHGs) and Global Warming Potentials (GWPs - 100 Yrs)						
GHG	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**
GWP	**1**	**28**	**265**	**Varies**	**Varies**	**23,500**

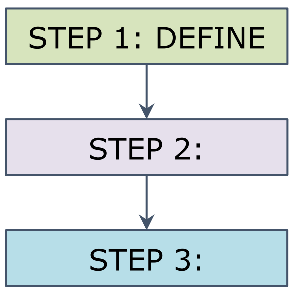
➔ *Greenhouse Gases (GHGs):* Greenhouse gas emissions are gases that trap heat in the atmosphere. Some greenhouse gases such as CO_2 occur naturally and are emitted into the atmosphere through natural processes and human activities. Other greenhouse gases are created and emitted solely through human activities. The principal GHGs that enter the atmosphere because of human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Refer Section 2.4 for more information.

➔ *Global Warming Potentials (GWPs):* The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one mass-based unit of a given GHG compared to one equivalent unit of carbon dioxide (CO_2) over a given period. The time-period used in this estimate is 100 years. Refer Section 2.4 for more information.

4.3.3 Specific instructions

- **Main Steps**

There are three primary steps in completing the GHGI. Estimation of GHG emissions from each source also includes these three steps.



➔ *STEP 1:* The first step in completing a GHGI is to determine the boundaries and emissions sources included within those boundaries.

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➔ *STEP 2:* The second step is to collect data for the defined annual period. This step is typically the most time consuming, since the data can be difficult to gather. This worksheet of the GHGI tool (Workbook) provides general guidance and other worksheets provide specific guidance for each emissions source, where necessary.

➔ *STEP 3:* The third step is to calculate emissions. This GHGI tool is designed to complete the emissions quantification step for the city or local government. Once the user enters data in this MS Excel worksheet, the emissions will be calculated and totaled on the "Summary" sheet.

- **How to use this GHGI tool**

➔ The GHG estimations are done in annual basis. In general, there is a Base year and one or more Analysis year/s. This document include data fields for the Base year and one Analysis year. More Analysis years could be added as required.

- Fill in City/Local Authority information in the "City Details" sheet. Include here a map indicating the geographical region covered in the Inventory.
- Provide information of the emission sources and custom emission factors in the "General Input Parameters" sheet for use in subsequent worksheets.

- The tool primarily uses default emission factors. Unless stated otherwise, all emission factors were obtained from the International Panel on Climate Change (IPCC).

- Use each of the sheets to input inventory data for the various activities. Make sure to choose custom emission factors, if any, and to select the proper units.

- Information on conversion of units is provided in "Conversion Table" sheet.

- The GHG emissions results for each activity types are provided in the "Summary Table" sheet, with an option to print the results.

- If the results do not show, please make sure that all the relevant options have been selected and that the correct Emission Factors have been chosen.

- To add more rows to any table, click on the "Insert Row" button next to the table. Do not try adding rows manually as that might affect the cell formulae.

Description of the Scope of the Inventory

- Accounting for GHG emissions in a city or local government is done under three scope of activities (refer Section 3.5).

Categories of Sources

- In total, there are six categories of GHG emission sources included in this GHGI: Energy, Transport, Waste, Industry, Forestry and Agriculture.

- Scope 1 includes six categories of emission sources, while two categories in Scope 2 and four categories in Scope 3 (refer Section 3.6).

How to Complete the Worksheets

➔ Following tables of this section provide step-wise instructions by source category for the data entry operators to complete the worksheets of this GHGI tool (Workbook).

♦ **Energy Sector - Stationary Combustion (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select the Sub-sector from the drop-down. Main Sub-sectors include Domestic, Commercial, and Industry.
3	Select the Fuel from the drop-down. Main fuel categories include Diesel, Furnace oil, Kerosene, Coal, LPG, and Biogas.
4	Enter the amount of fuel used and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all the Sub-sectors for the base year and reporting year/s.
7	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Energy Sector - Stationary Combustion (Scope 2)**	
1	Enter the Year from the drop-down.
2	Select the Sub-sector from the drop-down. Main Sub-sectors include Domestic, Commercial, Industry and Street lighting.
3	Enter the amount of electrcity consumed and the units.
4	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
5	Repeat step 1 to 4 for all the Sub-sectors for the base year and reporting year/s.
6	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Energy Sector - Electricity Exported (Renewable Energy - Net Plus Scheme) (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select the Sub-sector from the drop-down. Main Sub-sectors include Domestic, Commercial, Industry and Street lighting.
3	Enter the amount of electrcity exported and the units.
4	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
5	Repeat step 1 to 4 for all the Sub-sectors for the base year and reporting year/s..
6	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Transport Sector - In-boundary Transportation (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select Vehicle Type from the drop-down.

3	Select Fuel Type from the drop-down.
4	Enter the amount of distance travelled and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all types of vehicles.
7	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦	**Transport Sector - Out-of-boundary Transportation (Scope 3)**
1	Enter the Year from the drop-down.
2	Select Vehicle Type from the drop-down.
3	Select Fuel Type from the drop-down.
4	Enter the amount of distance travelled and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all types of vehicles for the base year and reporting year/s.
7	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦	**Industry Sector - Industrial Processes and Product Use (Scope 1)**
1	Enter the Year from the drop-down.
2	Select the Sub-sector from the drop-down.
3	Select the Production/Rawmaterial type from the drop-down.
4	Enter the amount of production/raw materials and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all the Sub-sectors for the base year and reporting year/s.
7	Total GHG emissions for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦	**Waste - MSW (Scope 1)**
1	Enter the Year from the drop-down.
2	Select the sub-sector from the drop-down.
3	Select waste management technique from the drop-down.
4	Enter the amount of waste and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all the waste management techniques in the sub-sector.
7	Repeat step 1 to 6 for all the sub-sectors for the base year and reporting year/s.
8	Total GHG emissions for the sub-sectors will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦	**Waste - Wastewater (Scope 1)**
1	Enter the Year from the drop-down.
2	Select the sub-sector from the drop-down.

3	Select wastewater treatment technique from the drop-down.
4	Enter the amount of wastewater and the units.
5	Select the emission factor category (Default or Custom Emission Factors) from the drop-down.
6	Repeat step 1 to 5 for all the wastewater treatment technique in the sub-sector.
7	Repeat step 1 to 6 for all the sub-sectors for the base year and reporting year/s.
8	Total GHG emissions for the sub-sectors will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Forestry and Carbon Sink (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select the Land-use from the drop-down.
3	Enter the extend of the land and the units.
4	Select the emission/removal factor category (Default or Custom Emission Factors) from the drop-down.
5	Repeat step 1 to 4 for all the land categories for the base year and reporting year/s.
6	Total GHG emissions / removal for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Agriculture & Livestock - Agriculture (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select the Land-use from the drop-down.
3	Enter the extend of the land and the units.
4	Select the emission/removal factor category (Default or Custom Emission Factors) from the drop-down.
5	Repeat step 1 to 4 for all the land categories for the base year and reporting year/s.
6	Total GHG emissions / removal for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

♦ **Agriculture & Livestock - Livestock (Scope 1)**	
1	Enter the Year from the drop-down.
2	Select the Animal type from the drop-down.
3	Enter the animal population.
4	Select the emission/removal factor category (Default or Custom Emission Factors) from the drop-down.
5	Repeat step 1 to 4 for all animal categories for the base year and reporting year/s.
6	Total GHG emissions / removal for the activities will be calculated at the bottom of the table and will be available in the "Summary Table" sheet for both base year and reporting year/s.

4.3.4 Conversion tables

The GHG estimates are done through a combination of activity data and emission factors that involves a range of physical parameters different units. The sources of information may use different units and the work sheets of this GHGI use specific units for reporting and estimation. Therefore, it is important to identify the original units and convert them to the units used in this document, for which following tables could be used:

♦ Mass			
Convert From	**Convert To**	**Multiply By**	**Units**
pounds (lb)	gram (g)	453.6	g / lb
pounds (lb)	kilogram (kg)	0.4536	kg / lb
pounds (lb)	metric ton	0.0004536	metric ton / lb
kilogram (kg)	pounds (lb)	2.205	lb / kg
gram (g)	short ton	0.000001102	short ton / g
kilogram (kg)	short ton	0.001102000	short ton / kg
metric ton	short ton	1.102	short ton / metric ton
pounds (lb)	short ton	0.0005	short ton / lb
short ton	short ton	1.00	short ton / short ton
metric ton	pounds (lb)	2,205	lb / metric ton
metric ton	kilogram (kg)	1,000	kg / metric ton

♦ Volume			
Convert From	**Convert To**	**Multiply By**	**Units**
standard cubic foot (scf)	barrel (bbl)	0.1781	bbl / scf
standard cubic foot (scf)	liters (L)	28.32	L / scf
standard cubic foot (scf)	cubic meters (m3)	0.02832	m3 / scf
US gallon (gal)	barrel (bbl)	0.0238	bbl / gal
US gallon (gal)	liters (L)	3.785	L / gal
US gallon (gal)	cubic meters (m3)	0.003785	m3 / gal
barrel (bbl)	US gallons (gal)	42	gal / bbl
barrel (bbl)	liters (L)	158.99	L / bbl
barrel (bbl)	cubic meters (m3)	0.1589	m3 / bbl
liters (L)	cubic meters (m3)	0.001	m3 / L
liters (L)	US gallon (gal)	0.2642	gal / L
cubic meters (m3)	barrel (bbl)	6.2897	bbl / m3
cubic meters (m3)	US gallon (gal)	264.2	gal / m3
cubic meters (m3)	liters (L)	1,000	L / m3

♦ Energy			
Convert From	**Convert To**	**Multiply By**	**Units**
kilowatt hour (kWh)	Btu	3,412	Btu / kWh

kilowatt hour (kWh)	kilojoules (KJ)	3,600	KJ / kWh
megajoule (MJ)	gigajoules (GJ)	0.001	GJ / MJ
gigajoule (GJ)	million Btu (mmBtu)	0.9478	mmBtu / GJ
gigajoule (GJ)	kilowatt hours (kWh)	277.8	kWh / GJ
Btu	joules (J)	1,055	J / Btu
million Btu (mmBtu)	gigajoules (GJ)	1.055	GJ / mmBtu
million Btu (mmBtu)	kilowatt hours (kWh)	293	kWh / mmBtu
therm	kilowatt hours (kWh)	29.3	kWh / therm

♦ **Distance**			
Convert From	**Convert To**	**Multiply By**	**Units**
mile	kilometers (km)	1.609	km / mile
nautical mile	miles	1.15	mile / nautical mile
kilometer (km)	miles	0.622	mile / km

♦ **Other**			
peta (P)	1,000,000,000,000,000	deci (d)	0.1
tera (T)	1,000,000,000,000	centi (c)	0.01
giga (G)	1,000,000,000	milli (m)	0.001
mega (M)	1,000,000	micro (μ)	0.000001
kilo (K)	1,000	nano (n)	0.000000001
hecto (h)	100	Molecular Weigh of C	12
deca (da)	10	Molecular Weight of CO_2	44

4.3.5 Default values tables

In case of emission factors, the majority of data will be based on the default values given in IPCC guidelines (2006 and 2019). In some cases, locally appropriate quantities could be used, whenever such data exists. Grid emission factors, fuel properties and composition of waste are some examples. Further, in case of lack of activity data, default values based on national figures can be defined. Following tables present default values under different sectors relevant to this GHGI workbook.

- **Energy Sector**

♦ **GHG Emission Factor for Electricity (Ref: SLSEA)**			
Energy Source	**Year**	**Emission Factor (ton CO_2e/MWh)**	
		Operating Margin	**Average Emission**
Grid Electricity	2012	0.7035	
	2013	0.6993	

	2014	0.6938	0.5077
	2015	0.6896	0.4753
	2016	0.6987	0.5684
	2017	0.6993	0.5865
	2018	0.7044	0.4694

♦ **Grid Connected Solar PV Plants**	
Electricity generation potential (kWh/kW/month)	120

♦ **Default Calorific Values and Emission Factors for Stationary Combustion in kg GHG/TJ (Ref: Tier 1 - IPCC 2006)**											
Fuel	**Simplified Fuel Name**	**Net calorific value (TJ/Gg)**	**CO_2**	**CH_4**				**N_2O**			
				Energy industries	**Manufac. industries/ construction**	**Commercial/ Institutional**	**Residential**	**Energy industries**	**Manufacturing industries/ construction**	**Commercial/ Institutional**	**Residential**
1. Liquild fuel											
Crude oil	Crude Oil	42.3	73,300	3	3	10	10	0.6	0.6	0.6	0.6
Orimulsion	Orimulsion	27.5	77,000	3	3	10	10	0.6	0.6	0.6	0.6
Natural Gas Liquids	Natural Gas Liquids	44.2	64,200	3	3	10	10	0.6	0.6	0.6	0.6
Gasoline	Motor Gasoline	44.3	69,300	3	3	10	10	0.6	0.6	0.6	0.6
	Aviation gasoline	44.3	70,000	3	3	10	10	0.6	0.6	0.6	0.6
	Jet gasoline	44.3	70,000	3	3	10	10	0.6	0.6	0.6	0.6
Jet kerosene	Jet kerosene	44.1	71,500	3	3	10	10	0.6	0.6	0.6	0.6
Other Kerosene	Kerosene	43.8	71,900	3	3	10	10	0.6	0.6	0.6	0.6
Shale oil	Shale oil	38.1	73,300	3	3	10	10	0.6	0.6	0.6	0.6
Gas/Diesel oil	Diesel Oil	43.0	74,100	3	3	10	10	0.6	0.6	0.6	0.6

Residual fuel oil	Residual Oil	40.4	77,400	3	3	10	10	0.6	0.6	0.6	0.6
Liquefied Petroleum Gases	LPG	47.3	63,100	1	1	5	5	0.1	0.1	0.1	0.1
Ethane	Ethane	46.4	61,600	1	1	5	5	0.1	0.1	0.1	0.1
Naphtha	Naphtha	44.5	73,300	3	3	10	10	0.6	0.6	0.6	0.6
Bitumen	Bitumen	40.2	80,700	3	3	10	10	0.6	0.6	0.6	0.6
Lubricants	Lubricants	40.2	73,300	3	3	10	10	0.6	0.6	0.6	0.6
Petroleum Coke	Petroleum Coke	32.5	97,500	3	3	10	10	0.6	0.6	0.6	0.6
Refinery Feedstocks	Refinery Feedstocks	43.0	73,300	3	3	10	10	0.6	0.6	0.6	0.6
Other oil	Refinery Gas	49.5	57,600	1	1	5	5	0.1	0.1	0.1	0.1
	Paraffin Waxes	40.2	73,300	3	3	10	10	0.6	0.6	0.6	0.6
	White Spirit and SBP	40.2	73,300	3	3	10	10	0.6	0.6	0.6	0.6
	Other Petroleum Products	40.2	73,300	3	3	10	10	0.6	0.6	0.6	0.6
2. Solid Fuel											
Anthracite	Anthracite	26.4	98,300	1	10	10	300	1.5	1.5	1.5	1.5
Coking Coal	Coking Coal	28.2	94,600	1	10	10	300	1.5	1.5	1.5	1.5

Other Bituminous Coal	Other Bituminous Coal	25.8	94,600	1	10	10	300	1.5	1.5	1.5	1.5
Sub-Bituminous Coal	Sub-Bituminous Coal	18.9	96,100	1	10	10	300	1.5	1.5	1.5	1.5
Lignite	Lignite	11.9	101,000	1	10	10	300	1.5	1.5	1.5	1.5
Oil Shale and Tar Sands	Oil Shale and Tar Sands	8.9	107,000	1	10	10	300	1.5	1.5	1.5	1.5
Brown Coal Briquettes	Brown Coal Briquettes	20.7	97,500	1	10	10	300	1.5	1.5	1.5	1.5
Patent Fuel	Patent Fuel	20.7	97,500	1	10	10	300	1.5	1.5	1.5	1.5
Coke	Coke Oven Coke and Lignite Coke	28.2	107,000	1	10	10	300	1.5	1.5	1.5	1.5
	Gas Coke	28.2	107,000	1	1	5	5	0.1	0.1	0.1	0.1
Coal Tar	Coal Tar	28.0	80,700	1	10	10	300	1.5	1.5	1.5	1.5
3. Gas Fuel											
Derived Gases	Gas Works Gas	38.7	44,400	1	1	5	5	0.1	0.1	0.1	0.1
	Coke Oven Gas	38.7	44,400	1	1	5	5	0.1	0.1	0.1	0.1
	Blast Furnace Gas	2.47	260,000	1	1	5	5	0.1	0.1	0.1	0.1

	Oxygen Steel Furnace Gas	7.06	182,000	1	1	5	5	0.1	0.1	0.1	0.1
Natural Gas	Natural Gas	48.0	56,100	1	1	5	5	0.1	0.1	0.1	0.1
4. Other Fossil Fuel											
Municipal Wastes (non-biomass fraction)	Municipal Wastes (non-biomass fraction)	10.0	91,700	30	30	300	300	4	4	4	4
Industrial Wastes	Industrial Wastes	NA	143,000	30	30	300	300	4	4	4	4
Waste Oils	Waste Oils	40.2	73,300	30	30	300	300	4	4	4	4
Peat	Peat	9.76	106,000	1	2	10	300	1.5	1.5	1.4	1.4
5. Biomass											
Solid Biofuels	Wood / Wood Waste	15.6	112,000	30	30	300	300	4	4	4	4
	Sulphite lyes (Black Liquor)	11.8	95,300	3	3	3	3	2	2	2	2
	Other Primary Solid Biomass	11.6	100,000	3	30	300	300	4	4	4	4
	Charcoal	29.5	112,000	3	200	200	200	4	4	1	1
Liquid Biofuels	Biogasoline	27.0	70,800	1	3	10	10	0.6	0.6	0.6	0.6
	Biodiesels	27.0	70,800	1	3	10	10	0.6	0.6	0.6	0.6

	Other Liquid Biofuels	27.4	79,600	1	3	10	10	0.6	0.6	0.6	0.6
Gas Biomass	Landfill Gas	50.4	54,600	30	1	5	5	0.1	0.1	0.1	0.1
	Sludge Gas	50.4	54,600	1	1	5	5	0.1	0.1	0.1	0.1
	Other Biogas	50.4	54,600	1	1	5	5	0.1	0.1	0.1	0.1
Other nonfossil fuels	Municipal Wastes(biomass fraction)	11.6	100,000	30	30	300	300	4	4	4	4

▪ Transport Sector

♦ Default Emission Factors for Mobile Combustion (Ref: Tier 1 - IPCC 2006)

Fuel Type	Net calorific value (TJ/Gg)	Emission Factor(Tier 1)		
		CO_2 (kg GHG/TJ)	CH_4 (kg GHG/TJ)	N_2O (kg GHG/TJ)
Motor Gasoline (Petrol)	44.3	69,300	25	8
Diesel Oil	43.0	74,100	3.9	3.9
LPG	47.3	63,100	62	0.2
Kerosene	43.8	71,900	0	0
Lubricants	40.2	73,300	0	0
CNG	48.0	56,100	92	3
LNG	48.0	56,100	92	3

▪ Waste Sector (Municipal Solid Waste - MSW)

♦ MSW Generation

Per Capita Waste Generation (kg/cap/day)	
Western Province	Other Provinces
0.52	0.36
Fraction of MSW generation by daily commuters	
Commuters in	0.7
Commuters out	0.3

♦ MSW Composition (%)

Compostable	61.26
Recyclable	22.24
Other	16.50
Combustible in Recyclable	91.55
Combustible in Other	53.52
Total Combustible	29.19

♦ MSW Collection

Source/Waste Stream	Waste Custodian/ Entity	Collection Factor	
		Western Province	Other Provinces
Domestic / MSW	Local Authorities (LAs)	0.6	0.25
	Individual generators	0.4	0.75

♦ Composition and Properties of MSW							
Category	**Nature**	**Composition (% Weight)**	**Dry Matter (DM) %**	**DOC % DM**	**C Fraction in DM**	**Fossil Fraction in C**	**Fraction of DOC which actually degrades**
Kitchen waste	Compostable (Biodegradable)	52.43	30.0	38.0	0.380	0.00	0.7
Grass/ Garden waste	Compostable	8.83	40.0	49.0	0.490	0.00	0.7
Wood waste	Combustible	8.83	75.0	50.0	0.500	0.00	0.1
Paper	Combustible/ Recyclable	9.96	90.0	44.0	0.460	0.01	0.5
Textiles	Combustible/ Recyclable	3.04	80.0	30.0	0.500	0.20	0.5
Soft Plastics	Combustible/Re cyclable	5.75	100.0	0.0	0.750	1.00	0.0
Hard Plastics	Combustible/ Recyclable	1.03	100.0	0.0	0.750	1.00	0.0
Rubber & leather	Combustible/ Recyclable	0.58	84.0	47.0	0.670	0.20	0.1
Metal	Recyclable	0.94	100.0	0.0	0.000	0.00	0.0
Glass & bottles	Recyclable	0.94	100.0	0.0	0.000	0.00	0.0
Stone & ceramic	Residue	4.54	100.0	0.0	0.000	0.00	0.0
Other	Residue	3.13	90.0	0.0	0.030	1.00	0.0

♦ GHG Emission Factors in kg/t of MSW					
GHG	**Composting**	**Dumping**	**Open Burning**	**Biogas**	**Incineration**
CO2	0.00	0.0	567.90	0.00	979.20
CH4	4.00	61.60	6.50	1.00	0.20
N2O	0.24	0.0	0.15	0.00	0.047
CO2-e	175.6	1724.8	789.65	28	997.255

♦ Emission Factors of Incineration			
Emission Factors (On a wet weight basis)		**CH4 (kg/t)**	**N2O (g/t)**
Continuous incineration	Stoker	0.2	47
	Fluidised bed	0.0	67
Semi-continuous incineration	Stoker	6	41
	Fluidised bed	188	68
Batch type incineration	Stoker	60	56
	Fluidised bed	237	221

♦ Oxidation Factors of MSW	
Technology	**Oxidation Factor**
Open Burning	0.70
Incineration	1.00

♦ CH4 Emissions in SWDS	
CH4 Correction Factor (MCF)	**Fraction of C Released as CH4**
0.6	0.5

♦ MSW management techniques				
Source/ Waste Stream	**Waste Custodian/ Entity**	**Management Technique**	**Western Province**	**Other Provinces**
Domestic & Commercial / MSW	Local Authorities (LAs)	Recycling (assumed) as a fraction of recyclables	0.09	0.075
		Composting (assumed) as a fraction of collection	0.15	0.03
		Waste to Energy (Incineration) as a fraction of collection	0.20	0.00
		Waste to Energy (Anaerobic Digestion) as a fraction of collection	0.00	0.00
		SWDSs (the balance)	0.770	0.976
		Open Burning (in SWDs, as a fraction of SWDs)	0.10	0.20
	Individual generators	Recycling – informal collectors as a fraction of recyclables	0.20	0.10
		Composting/Burying (Compostable amount)	0.61	0.61
		Waste to Energy (Anaerobic Digestion) as a fraction of collection	0.00	0.00
		Open Burning (balance recyclables)	0.07	0.15

▪ Waste Sector (Domestic Waste Water - DWW)

♦ Emission Factors of DWW		
Technology	**Emission Factors**	
	kg CH4/person/yr	**g N2O/person/year**
Latrine	0.745	49.1
Septic tanks	3.723	49.1
Centralized, aerobic treatment	0.000	4.0

♦ Treatment Technologies of DWW		
Sector	**Technology**	**% Population**
Rural	Latrine	71
Urban - low income	Septic tanks	23
Urban - high income	Centralized plants	0.1
	Septic tanks	5.9

GLOSSARY

Activity	Refers to a practice or ensemble of practices that take place on a demarcated area over a given period of time that result in the creation of GHG emissions either directly (e.g., use of household furnaces and vehicles with internal combustion engines) or indirectly (e.g., use of electricity created through combustion of fossil fuels at a power plant, consumption of goods and services whose production, transport and/or disposal resulted in creation of GHG emissions directly or indirectly).
Activity data	Data on the magnitude of a human activity resulting in GHG emissions or removals taking place during a given period of time. Data on energy/fuel use, input material, product output, km travel, land area, management system, lime & fertilizer use and waste generation are examples of activity data that might be used to compute GHG emissions.
Anthropogenic emissions	GHG emissions that are a direct result of human activities or are the result of natural processes that have been affected by human activities.
Analysis year	The single year timeframe for which GHG emissions are being quantified and reported. Typically, the analysis year refers to when the emissions occur, but in some cases it refers to when the activity occurs (e.g., future emissions resulting from disposal of waste in the analysis year).
Base year	The year against which the GHG emissions are compared over time.
Biogenic emissions from combustion	CO2 emissions produced from combusting a variety of biofuels and biomass, such as biodiesel, ethanol, wood, wood waste and landfill gas.
Biomass	Non-fossilized organic material originating from plants, animals, and micro-organisms, including products, byproducts, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes, including gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material

Carbon dioxide (CO_2)	The most common of the six primary GHGs, consisting of a single carbon atom and two oxygen atoms, and providing the reference point for the GWP of other gases. (Thus, the GWP of $CO_2$is equal to 1.)
Carbon footprint	The total volume of GHG emissions caused by a community, organization, event, product, or person.
Carbon (or GHG) sink	A biological system or other natural environment, such as a forest or a body of water, that absords more carbon dioxide from the atmosphere than it releases.
Carbon stock	The carbon embodied in a biological system, such as oceans, trees and the atmosphere. A carbon stock that is taking up carbon is called a "sink" and one that is releasing carbon is called a "source".
CO_2 equivalent (CO_2e)	The universal unit for comparing emissions of different GHGs expressed in terms of the GWP of one unit of carbon dioxide.
Emission boundary	GHG emission accounting and reporting boundaries for an entity such as a city or local government
Emission factor (EF)	A unique value for determining an amount of a GHG emitted on a per unit activity basis (for example, metric tons of CO_2 emitted per GJ of coal combusted, or metric tons of CO_2 emitted per kWh of electricity consumed).
Fugitive emissions	Emissions that are not physically controlled but result from the intentional or unintentional release of GHGs. They commonly arise from the production, processing, transmission, storage and use of fuels or other substances, often through joints, seals, packing, gaskets, etc. Examples include HFCs from refrigeration leaks, SF_6 from electrical power distributors, and CH_4 from solid waste landfills.
Geographical boundary	The boundaries that determine the operations owned or controlled by the reporting entity such as city or local government.
Global warming potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one mass-based unit of a given GHG compared to one equivalent unit of carbon dioxide (CO_2) over a given period of time.

Greenhouse gas emissions (GHGs)	Greenhouse gas emissions are gases that trap heat in the atmosphere. Some greenhouse gases such as carbon dioxide occur naturally and are emitted into the atmosphere through natural processes and human activities. Other greenhouse gases are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases (hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride).
Greenhouse gas emission sources	Any physical process or activity that releases GHG emissions into the atmosphere (e.g., vehicle exhaust from combustion of gasoline, furnace exhaust from the combustion of oil, emissions from cook stoves due to combustion of LPG, power plant exhaust from combustion of coal for the production of electricity).
Heating value	The amount of energy released when a unit mass of fuel is burned completely (Unit: MJ/kg).
Higher heating value (HHV)	The high or gross heat content of the fuel with the heat of vaporization included. The water vapor is assumed to be in a liquid state (Unit: MJ/kg).
Hydrofluorocarbons (HFCs)	One of the six primary GHGs, a group of manmade chemicals with various commercial uses (e.g., refrigerants) composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most HFCs are highly potent GHGs with 100-year GWPs in the thousands.
Intergovernmental Panel on Climate Change (IPCC)	International body of climate change scientists. The role of the IPCC is to assess the scientific, technical and socio-economic information relevant to the understanding of the risk of human-induced climate change
Inventory	A comprehensive, quantified list of GHG emissions and sources.
Lower heating value (LHV)	Low or net heat content with the heat of vaporization excluded. The water is assumed to be in the gaseous state.

Methane (CH_4)	One of the six primary GHGs, consisting of a single carbon atom and four hydrogen atoms, possessing a GWP of 21, and produced through the anaerobic decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion.
Nitrous oxide (N_2O)	One of the six primary GHGs, consisting of two nitrogen atoms and a single oxygen atom, possessing a GWP of 310, and typically generated as a result of soil
Perfluorocarbons (PFCs)	One of the six primary GHGs, A group of man-made chemicals composed of one or two carbon atoms and four to six fluorine atoms, containing no chlorine.Originally introduced as alternatives to ozone depleting substances, PFCs have few commercial uses and are typically emitted as by-products of industrial and manufacturing processes. PFCs have very high GWPs and are very long-lived in the atmosphere.
Process emissions	Emissions from physical or chemical processing rather than from fuel combustion. Examples include emissions from manufacturing cement, aluminum, adipic acid, ammonia, etc.
Removal factor (RF)	A unique value for determining an amount of GHG removed on a per unit activity basis (for example, metric tons of CO_2 removed per ha of land area per year, or kg of CO_2 emitted per tree per year).
Sulfur hexafluoride (SF_6)	One of the six primary GHGs, consisting of a single sulfur atom and six fluoride atoms, possessing a very high GWP of 23,900, and primarily used in electrical transmission and distribution systems
United Nations Framework Convention on Climate Change (UNFCCC)	Signed in 1992 at the Rio Earth Summit, the UNFCCC is a milestone Convention on Climate Change treaty that provides an overall framework for international efforts to mitigate climate change. The Kyoto Protocol is a protocol to the UNFCCC.

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