Good Practice Study on GHG-Inventories for the Waste Sector in Non-Annex I Countries

On behalf of

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

Imprint

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15

E climate@giz.de
I www.giz.de/climate

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)

Responsible:
Oscar Zarzo

Authors:
Jakob Graichen, Margarethe Scheffler, Vanessa Cook
Öko-Institut e.V., Freiburg / Berlin / Darmstadt

With inputs from Voltaire Acosta, Johannes Fromman, Karolin Kölling, Rocío Lichte, Kirsten Orschulok and Oscar Zarzo, GIZ

Photo credits (title page):
GIZ/Nour El Refai

Berlin, August 2015

This report was prepared for the project "Information Matters: Capacity Building for Ambitious Reporting and Facilitation of International Mutual Learning through Peer-to-Peer Exchange" which forms part of the International Climate Initiative (IKI).

Since 2008, the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has been financing climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. Based on a decision taken by the German parliament (Bundestag), a sum of at least 120 million euros is available for use by the initiative annually. For the first few years the IKI was financed through the auctioning of emission allowances, but it is now funded from the budget of the BMUB. The IKI is a key element of Germany's climate financing and the funding commitments in the framework of the Convention on Biological Diversity. The Initiative places clear emphasis on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity. These efforts provide various co-benefits, particularly the improvement of living conditions in partner countries.

The IKI focuses on four areas: mitigating greenhouse gas emissions, adapting to the impacts of climate change, conserving natural carbon sinks with a focus on reducing emissions from deforestation and forest degradation (REDD+), as well as conserving biological diversity.

New projects are primarily selected through a two-stage procedure that takes place once a year. Priority is given to activities that support creating an international climate protection architecture, to transparency, and to innovative and transferable solutions that have an impact beyond the individual project. The IKI cooperates closely with partner countries and supports consensus building for a comprehensive international climate agreement and the implementation of the Convention on Biological Diversity. Moreover, it is the goal of the IKI to create as many synergies as possible between climate protection and biodiversity conservation.

www.international-climate-initiative.com

Contents

List of Tables and Figures

Tables

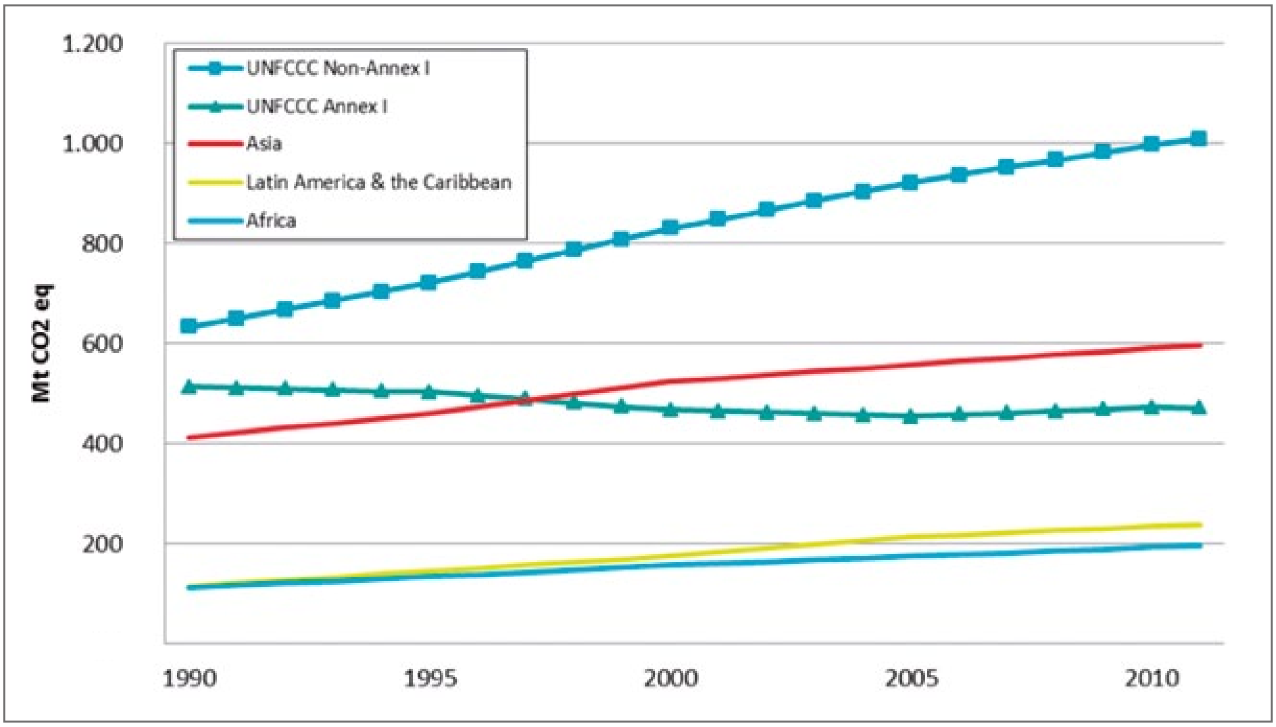
Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
ANGed	National Agency for Waste Management (Tunisia)
BOD	Biochemical Oxygen Demand
BUR	Biennial Update Report
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CRF	Common reporting format
DOC	Degradable organic carbon
EPA	Environmental Protection Agency, Ghana
F	Fraction of CH_4 in generated landfill gas
FOD	First Order Decay
Gg	Gigagram, the same as 1 kt or 1000 t
GIZ	German Agency on International Cooperation
JICA	Japan International Cooperation Agency
K	Methane generation rate constant or half life time
MBT	Mechanical Biological treatment
MCF	Methane Correction Factor
MSW	Municipal solid waste
MSWD	Municipal solid waste disposal
NAI	Non-Annex I
NC	National Communication
NIR	National Inventory Submission
NAMAs	Nationally Appropriate Mitigation Action
N_2O	Nitrous oxide
OX	Oxidation factor
QA/QC	Quality Assurance, Quality control
R	Recovery
SWD	Solid waste disposal
SWDS	Solid waste disposal sites
TOW	Total organically degradable carbon

Non-technical summary

Greenhouse gas emissions arising from the treatment and disposal of liquid and solid waste need to be covered by the greenhouse gas (GHG) inventories by both, developed and emerging and developing countries in their reports to the United Nations Framework Convention on Climate Change (UNFCCC). While the emissions from this sector are relatively low, they have risen continuously in developing countries due to changing production and consumption patterns (Figure 1-1). The experience gathered with the Clean Development Mechanism in developing countries and the emission reduction measures in industrialized countries have shown that significant emission reductions at relatively low costs are possible in this sector. The sector also has a great potential to achieve sustainable development co-benefits, which is a critical factor in the decision-making of countries. As a first step towards implementing policies and measures, it is necessary to adequately quantify these emissions, understand in which subsectors they originate and what the main reasons for these emissions are.

Figure 1-1: Development of GHG emissions of the waste sector



Source: Öko-Institut based on World Resources Institute, 2015

A high-quality GHG inventory is able to answer these questions but compilers need to overcome some obstacles during inventory preparation: decisions and knowledge about waste generation and treatment is often taken at a local level with limited aggregation of data at the national level. In addition to waste generation data, it is necessary to obtain information on waste composition and treatment for inventory compilation. In many developing countries, these data problems are exacerbated because of an only partially formalised sector; relevant shares of waste are disposed at dumps, are burnt on site or are recycled by the informal recycling sector. Thus, in developing countries, information is mostly available from the formal waste management sector while data on the significant portion of waste being unofficially managed by the informal sector, among other in recycling, is unknown.

The purpose of this study is to support the preparation of GHG inventories in the waste sector through good practice examples which can be adopted in other countries. This report complements the existing UNFCCC material with real life examples in the waste sector from different countries. It is directed at persons involved in the compilation of GHG inventories in the waste sector especially in non-Annex I1 countries. In addition the study analy-

1 Non-Annex I Parties are mostly developing countries, recognized by the UNFCCC as being especially vulnerable to the adverse

ses the interlinkages between inventories and emission mitigation actions in the sector and gives an overview of different models and data sources for waste inventories. All analysed countries are applying the IPCC Guidelines and need to collect and determine the same data and parameters. While national circumstances differ, the problems can be similar and it might be possible to adapt an approach chosen in one country to help overcome obstacles in another.

Developing countries should submit updated GHG inventory information every two years as part of their Biennial Update Reports to the UNFCCC2. The Intergovernmental Panel on Climate Change (IPCC) has developed Guidelines for GHG inventory compilation3. In doing so, non-Annex I countries should use the 1996 IPCC Guidelines combined with the use of the 2000 IPCC Good Practice Guidance. The methodologies, explanations and default values provided in the latest version of these guidelines published in 2006 are greatly improved compared to the previous version. For that reason many non-Annex I countries have started to use the 2006 IPCC Guidelines, and they are encouraged to use the 2006 IPCC Guidelines by the UNFCCC, even if they are not required to do so.

The Guidelines also provide input on how to set up a national inventory system that helps utilize available resources effectively. The task of preparing a complete GHG inventory may seem daunting initially, but even with very limited resources it is possible to undertake initial estimates. Preparing estimates using the simplest IPCC methodology for each source category and default parameters is relatively straight forward. In subsequent submissions methodologies, data and parameters can then be refined and improved. The case of Ghana is a good example: the Ghanaian first National Communication4 was prepared by a single person; the second was prepared by a team and for the third different working groups were established. Starting small can also be advantageous if the inventory agency does not have adequate resources for the task: once an inventory has been published and been used on the national level (e.g. for policy development), it might be easier to dedicate more funding to updates and improvements.

In addition to the IPCC Guidelines, many other guiding documents exist and various multilateral, national and private institutions offer capacity building programmes.

This study outlines recommendations for general GHG inventory development and specific issues related to the preparation of GHG inventories in the waste sector in developing countries. The main ones include:

- The institutionalisation of the system, by developing and agreeing processes to avoid 'starting from scratch' whenever an inventory is prepared. Together with adequate documentation of assumptions, data sources and calculations, this greatly facilitates inventory preparation for each BUR and National Communication.
- Conducting key category assessment to consequently allocate resources and efforts to the most relevant categories.
- Using IPCC methodologies and default values to gap-fill missing data.
- Ensuring time series consistency in the transition from one source to the other, if different data sets are combined; and
- Improving the quality of the inventory as part of a continuous Quality Assessment / Quality Control (QA/QC) process, that should include an inventory improvement plan.

impacts of climate change and/or to the potential economic impacts of climate change response measures.

2 Biennial Update Reports are available under: http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

3 IPCC Guidelines are available under: http://www.ipcc-nggip.iges.or.jp/public/2006gl/

4 National Communications are available under: http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php

1. Introduction

Industrialized countries have been compiling annual greenhouse gas inventories for many years and gained much experience in their preparation. In contrast, many developing countries have only prepared two inventories and only for some years as part of their first and second National Communications to the UNFCCC. The requirements for Non-Annex I Parties have changed in recent years: during the Conference of the Parties in 2010 (COP 16), it was decided that developing countries will need to prepare Biennial Update Reports (BURs) every two years. Further guidelines on content and a consultation process were decided in subsequent COPs. In December 2014 developing countries were required to submit their first BUR. One of the chapters of the BUR is an updated GHG inventory covering all sources and gases. In the light of these new reporting requirements many developing countries are currently in the process of improving and institutionalising their national GHG inventory systems.

One of the sources that need to be covered by the inventory is GHG emissions from waste treatment and disposal. According to the IPCC Guidelines for GHG inventory compilation5, relevant activities are solid waste disposal, biological treatment of organic waste, waste burning and wastewater treatment and discharge. While the GHG emissions from this sector are relatively low, and were only responsible for 3.4% of global emissions in 2011 (World Resources Institute, 2015), they have risen continuously in developing countries. At the same time it is one of the sectors in which significant reductions are possible and affordable: Of all credits issued for CDM projects so far, 6% come from projects in this sector. Until 2030 these projects are expected to emit 7% of all credits, twice the share compared to the relevance of the waste sector for global emissions (UNEP and DTU, 2015). Reducing emissions from waste treatment, implementing modern waste management techniques and the avoidance of unregulated waste dumping and burning also have important co-benefits: Countries often put in place waste management policies to improve public service delivery and basic sanitation, protect public health and minimize leachate and gaseous emissions to the environment. A perspective on circular and low-carbon economy also highlights the sector, not only in terms of overall potential GHG emissions reduction, but also in its role in an urbanizing society that demands sustainable production and consumption. Secondary raw materials from recovered waste enhance resource efficiency of the industry. Measures also prolong landfill capacities, improve the working conditions of the semi- and informal waste sector, create new opportunities especially for jobs with higher qualifications and reduce subsidies through appropriate cost recovery schemes. Furthermore, co-benefits in terms of climate resilience and adaptation include the suitability of sites for waste management facilities, reduced impacts of flooding caused by the clogging of waterways while methane management options reduce explosion and fire risks at disposal sites.

Due to the emission reduction potential and the clear co-benefits many countries have started to develop Nationally Appropriate Mitigation Actions (NAMAs) in the sector. To be able to develop adequate policies for the waste sector it is necessary to have good data on current and expected future waste quantities and waste composition – data which could come from the greenhouse gas inventory for the sector.

1.1 Purpose and Structure of the Study

The purpose of this study is to support the preparation of GHG inventories in the waste sector through good practice examples which can be adopted in other countries. It is meant as a complement to the IPCC Guidelines and other training materials and shows how some common problems have been solved in different countries. The study is directed at persons involved in the compilation of GHG inventories in the waste sector especially in non-Annex I countries. It provides an overview of the relevant IPCC Guidelines for general GHG inventory preparation and provides guidance and compiles examples mainly from Non-Annex I countries on the development of GHG inventories specific to the waste sector. Based on the Guidelines and country examples specific recommendations are given for all source categories within the waste sector. In addition the study analyses the interlinkages between inventories and emission mitigation actions in the sector and gives an overview of different models and data sources for waste inventories. While national conditions in each country are different, there are some common problems such as lack of activity data, incomplete information, lack of capacity, and limited resources for inventory development.

5 IPCC Guidelines are available under: http://www.ipcc-nggip.iges.or.jp/public/2006gl/

The analysis has focused on current practice for GHG inventory development for the waste sector in different countries and it followed a three-stepped approach:

Identification of participating countries: In a first screening the publicly available information from 35 countries was compiled and assessed. Based on that first assessment 16 countries were identified for the inclusion in this study.6 The selection criteria included the application of good practice (see Box 1) in inventory development, regional distribution, coverage of all source-categories, choice of IPCC Guidelines, quality of documentation and existing contacts with inventory developers. Examples from three Annex I countries are also included especially concerning the development of inventory systems.

Desk Study: Good practice examples for all source categories in the waste sector were identified from the available documents of the 16 participating countries.

Direct Interviews: In a final step, six countries were selected for personal or telephone interviews. The interviews were used to discuss selected issues in more detail.

1.2 Scope of the study

The countries included in the study and documents used are shown in Annex II in Table 7-1; links to all publicly available documents used are included in Annex II and the References.

Currently developing countries should use the 1996 IPCC Guidelines; in addition they are encouraged to use the 2000 IPCC Good Practice Guidance (UNFCCC, 2014)7. Nevertheless, this study is based on the 2006 IPCC Guidelines for three main reasons:

The methodologies, explanations and availability of default values in the 2006 Guidelines are greatly improved compared to the previous versions. The provision of a First Order Decay tool for solid waste disposal (see Chapter 3.1) especially facilitates the preparation of GHG inventories greatly. At the same time, the discontinued Tier 1 methodology, i.e., Mass Balance Method, in the 1996 Guidelines for that source category led to large uncertainties and, therefore, its application is no longer considered good practice.

Many developing countries have already started to use the 2006 Guidelines and more are expected to do so in the future. This report is aimed at helping developing countries in the preparation and improvement of robust waste inventories and is future-oriented.

The 2006 Guidelines include some new sources but the categories from the 1996 Guidelines remain valid. That means that countries can use methodologies from both documents depending on the source category and gradually migrate to the new guidelines.

Where relevant a comparison/reference to the 1996 Guidelines is made.

1.3 Context of the study

The study was conducted on behalf of the Information Matters project, a GIZ project funded by the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) under the International Climate Initiative (IKI) which aims to strengthen the in-country capacities for enhanced climate change-related reporting in four partner countries: Chile, the Dominican Republic, Ghana and the Philippines. Within this project, the specific needs and priorities of a Monitoring, Reporting and Verification system (MRV) and greenhouse gas (GHG) monitoring are identified in consultation with the partners and improved with tailored in-country capacity-building workshops and trainings.

Since 2008, the International Climate Initiative (IKI) of the BMUB has been financing climate and biodiversity projects in developing and newly industrializing countries, as well as in countries in transition. The Initiative places clear emphasis on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity. These efforts provide various co-benefits, particularly the improvement of living conditions in partner countries.

6 The 16 countries are Armenia, Brazil, Bulgaria, Chile, China, Germany, Ghana, India, Indonesia, Kazakhstan, Mexico, Namibia, Romania, South Africa, Tunisia and Vietnam.

7 UNFCCC, 2014, Handbook on Measurement, Reporting and Verification for developing Country Parties, UNFCCC Secretariat (http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/non-annex_i_mrv_handbook.pdf)

2. Good practice in GHG inventory development

2.1 Background

The purpose of this chapter is to provide an introduction to the chapters of the 2006 IPCC Guidelines relevant for the preparation of GHG inventories in general. Specifics that apply to the waste sector alone are included in Chapters 3.1 to 3.4. This background information is directed at readers unfamiliar with the Guidelines and explains the underlying concepts and methodologies. However, it does not cover all relevant issues and details and is therefore not sufficient as a standalone guide for the preparation of a national inventory.

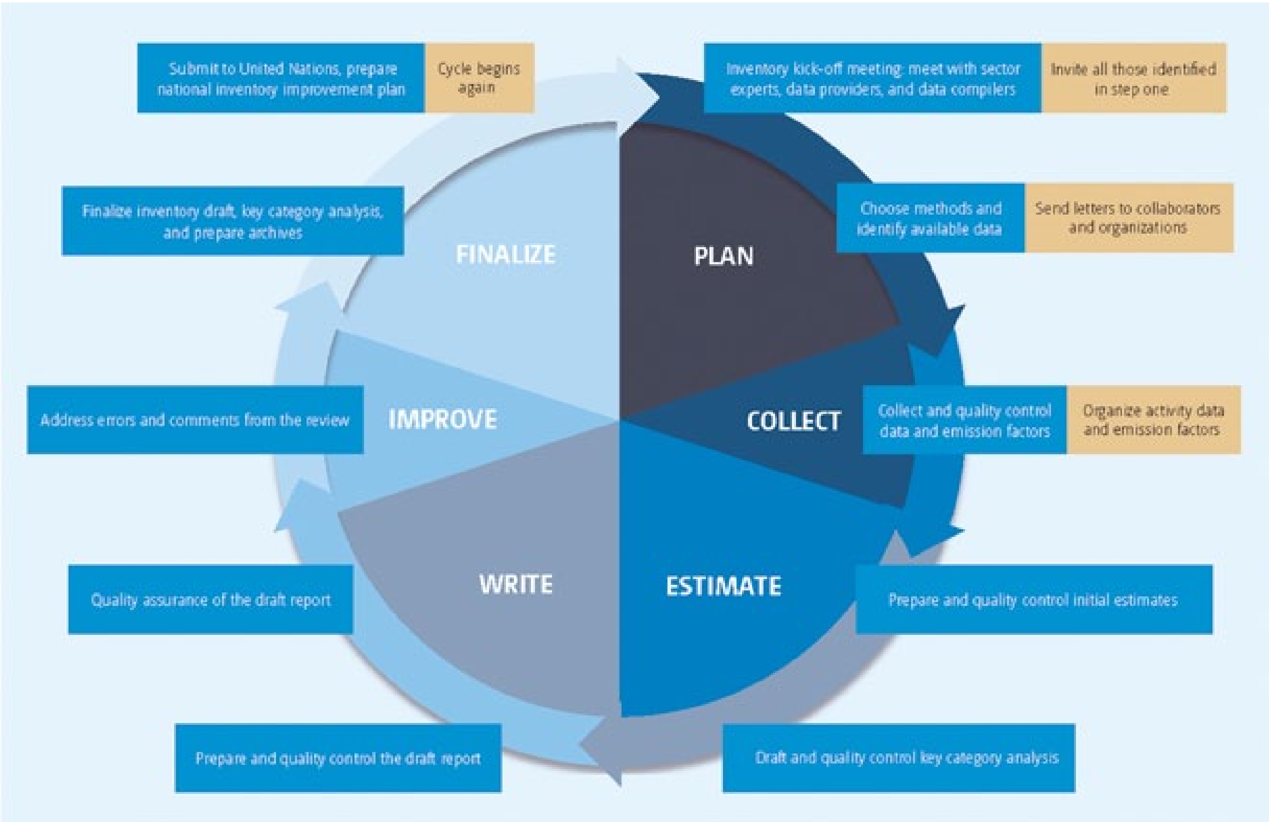
Preparing a complete national greenhouse gas inventory for any source category is a multi-stepped process which has to be repeated each time a new inventory report is prepared. Figure 2-1 shows a typical inventory cycle; additional details on good practice for the individual steps are provided below. Developing countries will not always be able to implement good practice for all steps and all sectors and are not required to do so by the UNFCCC. However, if circumstances allow, Non-Annex I Parties are encouraged to implement these steps to improve their GHG inventories. Good Practice allows the identification

Box 1: Good Practice in inventory development

The IPCC Guidelines define good practice as "a collection of methodological principles, actions and procedures […] to promote the development of high quality national greenhouse gas inventories. […] Inventories consistent with good practice are those which contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable." (IPCC, 2006, Vol. 1, p. 1.6) This definition implies that good practice depends on national circumstances, e.g. availability of activity data and existing resources for inventory development.

In this report, whenever a reference is made to good practice it refers to the IPCC definition and the principals, actions and procedures in the IPCC Guidelines. All country examples given are deemed good practice based on the available information. This does not mean that they are "best practice" in the sense of having minimal uncertainties in the emission estimates. For example, if a country has no activity data for some historic years it is good practice to apply the IPCC methodologies for gap-filling. Best practice would require complete activity data for all years which might not be practicable (i.e. not required for good practice).

Figure 2-1: Typical GHG inventory cycle



Source: US EPA quoted in (UNFCCC, 2014)

and prioritisation of areas for improvement and therefore a more efficient allocation of available resources.

2.2 Good practice requirements

2.2.1 Key categories and methodologies

According to IPCC, it is good practice to conduct a key source analysis to identify those source categories which contribute the most to the absolute emissions (level assessment) and/or to the change in GHG emissions over the years (trend assessment). Depending on previous inventories, there are three options for conducting a key source analysis (IPCC, 2006):

- Qualitative assessment if no previous inventories are available, if previous inventories are incomplete or to identify additional key sources based on further information,
- Approach 1: based on previous emission estimates,
- Approach 2: based on previous emission estimates and uncertainties.

These approaches) are cumulative, i.e. a country implementing Approach 2 should also apply Approach 1. The qualitative approach can then also be used to identify sources which are expected to become key, e.g. because of adopted policies that are expected to have a significant impact on future emissions.

Based on the above-mentioned analysis, the inventory compilers should consider the following for those categories identified as key:

- focusing available resources on key categories,
- applying higher tiers if possible without jeopardizing resources for other key categories; and
- focusing QA/QC procedures on these key categories.

In most but not all source categories the Guidelines provide different tiers for the estimation of GHG emissions and removals. While non-key categories can always be estimated using Tier 1, it is generally good practice to apply at least Tier 2 for key sources. In many cases the difference between the three tiers is as follows:

- Tier 1: use of national activity data but adopting default emission factors and other parameters as provided in the IPCC Guidelines.
- Tier 2: use of national activity data, emission factors and other parameters.
- Tier 3: use of site-specific activity data, emission factors and other parameters.

Details on the selection of the best tier are provided in decision trees for each source category in the respective volumes of the Guidelines.

2.2.2 Data collection and time series consistency

It is good practice for Annex I countries to prepare annual inventories for all years since 1990. This requires the availability of the necessary activity data and other parameters for those years. Depending on national circumstances, source category and methodology not all necessary information will be available. It is good practice to focus personnel and financial resources on those categories identified as key. The Guidelines include a list of potential national and international data sources, recommendations for data generation and the use of expert judgement.

Non-Annex I (NAI) countries do not have to prepare inventories for all years since 1990. National inventories have to be prepared for the year 1994 (alternatively 1990) within the first National communication and at least for the year 2000 within the Second National Communication. The Biennial Update Report (BUR) shall cover at least the inventory year no more than four years prior to the date of the submission. Thus, the first BUR submitted in 2014 shall provide the inventory for the year 2010 and the second BUR to be submitted in 2016 shall include the inventory for the year 2012 (UNFCCC, 2014). It is good practice (see Box 1 on page 15) to report for all years.

Often it is not possible to use one data source for the entire time period. Despite this it is good practice to ensure a consistent time series, i.e. to avoid breaks and jumps between data sets. The Guidelines include methodologies for gap filling and for combining different data sources. Time series consistency could also become an issue if the applied methodologies change within an inventory or between inventory submissions. Examples of this are when necessary data for higher tiers is only available for some years or when a source becomes key. In such cases it is good practice (see Box 1 on page 15) to ensure consistency and recalculate the entire time series if applicable.

2.2.3 Uncertainties

Estimates of GHG emissions in national inventories are never exact. Uncertainties in input data, incomplete coverage and errors in methodologies amongst others will lead to uncertainties in the estimation of GHG emissions and removals. It is good practice (see Box 1 on page 15) to estimate these uncertainties. Having detailed uncertainty estimates helps to prioritize the allocation of resources: it allows the application of the approach 2 in the key source analysis and can identify parameters with the highest impact on the overall uncertainty of a source category. Providing detailed guidance on estimating uncertainty for GHG inventories goes beyond the scope of this study. The IPCC 2006 guidelines provide detailed information on uncertainty estimates.

2.2.4 Quality Assurance and Quality Control

According to the 2006 Guidelines, Quality Assurance, Quality Control (QA/QC) and the verification system contribute to the objectives of good practice in inventory development, namely to improve transparency, consistency, comparability, completeness, and accuracy of national greenhouse gas inventories. In short, QC aims at minimizing errors in the inventory preparation, e.g. through automated checks of input data in regard to completeness and level. QA aims at checking whether the methodologies and data used are the most appropriate ones and is conducted after the inventory has been compiled. Verification is based on independent data to establish the reliability of the inventory. It can be an extension of both QC and QA.

It is good practice to implement QA/QC and verification procedures. This involves:

- development of a QA/QC plan with measurable objectives
- definitions of roles and responsibilities
- implementation of general and source-specific QC activities
- QA and verification procedures
- reporting and documentation of the data, assumptions, calculations and QA/QC procedures used for the inventory.

2.2.5 Reporting

The reporting of GHG inventories consists of data tables and a detailed report:

- CRF Tables: pre-defined data tables for each source category for emissions and activity data by gas and year;
- additional information, inter alia on methodologies, data sources, emission factors and other parameters, uncertainties and QA/QC procedures.

The Common Reporting Format (CRF) tables allow an easy access to all the relevant emission estimates and some underlying data for readers familiar with the format. Non-Annex I Parties only need to fill out some of those tables; for a detailed list, see (UNFCCC, 2014). It is good practice to complete all sheets and fill all cells. Notation keys can be used to explain otherwise empty cells, e.g. if a source does not occur in a country or if emissions are reported under another source category.

The additional information should facilitate the assessment and replication of the inventory by third parties. This implies that all relevant information, sources and assumptions should be listed in the report.

2.3 Country examples for general GHG inventory development

2.3.1 National GHG inventory systems and institutional settings

For compiling an inventory that complies with the requirements above, governments need to set up an institutional structure for data collection and reporting. Responsibilities for the different sectors have to be distributed among ministries; staff has to be trained and agreements with data providers have to be set up. The tables below – Table 2-1 and Table 2-2 – show examples of how the process of inventory compilation works in selected countries, with a focus on the waste sector.

In most countries, ministries or the environmental agency are responsible for compiling the GHG inventory. Many countries received external support for inventory compilation or outsourced the first inventories to external contractors while there were no capacities within the government available (see Table 2-1 Bulgaria)8. Ideally, trainings on inventory preparation with external experts resulted in building up sufficient capacity to prepare subsequent inventories in-house without depending on external support (see Table 2-1 Bulgaria, Tunisia, Vietnam).

Having a functional national system for GHG inventories in place makes inventory compilation much easier (see Table 2-2 Bulgaria). Countries without a functional national system may still be struggling with data availability and sufficient capacity for data collection (see Table 2-2 Vietnam). Existing statistical offices in Bulgaria, Indonesia and Tunisia already collect activity data on waste management; this data decreases the efforts for inventory development in the waste sector.

8 Some programs, institutions and material supporting inventory development are listed in Annex II.

Table 2-1: Inventory compilation and capacity building

Country	Description
Bulgaria	Bulgaria submitted its first inventory in the year 2003. Until 2007 the inventory had been compiled by an external private consultant. A governmental council finally approved the inventory and submitted it to the UNFCCC Secretariat. Since 2008 the inventory is compiled by the Executive Environment Agency which is responsible for the whole process of inventory planning, preparation and management. External support has been provided by the Federal Environment Agency of Austria in the form of a training program for Bulgarian inventory experts. The program covered all inventory sectors in a series of workshops carried out in the period December 2009 to June 2010 (Bulgaria, 2015).
Chile	Chile submitted its first Biennial Update Report in 2014 and a whole inventory in 2015. The Ministry of Environment in Chile was established in 2010; the creation of the Council of Ministers for Sustainability and Climate Change followed in 2014. Ministers involved in the Council have assigned sector-specific responsibilities among the relevant persons in the relevant ministries. The Oficina de Cambio Climático has the overall inventory coordination (Chile, 2014a).
Ghana	Ghana submitted its Second National Communication in the year 2011. The compilation of the NC has been institutionalized over time. The first NC was compiled by only one person; for the second NC a whole team was involved and for the compilation of the third NC working groups have been established. The Environmental Protection Agency in Ghana is responsible for the national GHG inventory and is also the leading agency for the waste inventory. It funded a project to rate the environmental friendly performance of companies, including their submission of emission data (http://www.epaghanaakoben.org/) (Ghana, 2015).
Indonesia	Indonesia submitted its Second National Communication in the year 2011. The Ministry of Public Works (MoPW) and the Ministry of Environment (MoE) carry the responsibility for the waste sector in Indonesia. Waste statistics are provided by the MoE; the MoPW deals with waste management issues. Within the MoE a team that is responsible for the compilation of GHG inventories has been set up. Indonesia receives external support on waste management and climate change issues, which is provided by the Japan International Cooperation Agency (JICA) and the German Development Agency (GIZ) (Indonesia, 2015).
Tunisia	Tunisia submitted its NC2 and the first BUR in 2014. The National Agency for Waste Management (ANGed) is responsible for the waste inventory. The process was initiated by a request from the GIZ to set up a team of experts for inventory compilation. Capacity building was provided by the Interprofessional Technical Centre for Studies on Air Pollution (CITEPA) and local experts that provided guidance on tools, data collection, estimation and report preparation. As a result, there is now sufficient capacity for inventory preparation in the Tunisian team. For compiling the inventory for the years 2011 and 2012, support is provided by an UNDP program. Tunisia expects to improve methodologies and potentially move to higher tiers in the next inventory; the work conducted for the first inventory is considered a good basis for further improvements (Tunisia, 2015).
Vietnam	Vietnam submitted the Second National Communication to the UNFCCC in 2010. The first Biennial Update Report was submitted in 2014. JICA provided support to compile the inventories for the year 2005 and 2010. The inventory 2010 for the waste sector has been compiled by an expert from the Vietnam Environmental Administration. Japanese consultants provided support during the inventory preparation and guidance to the expert. The inventory for the year 2012 will be compiled in-house without external support (Vietnam, 2015).

Source: Compilation by Öko-Institut

The motivation for preparing GHG inventories in most NAI countries was to comply with the UNFCCC reporting requirements. Data collection in the waste sector can be complex and time-consuming and ideally the results should be used for purposes beyond inventory compilation. Activity data used to calculate emissions from landfilling, open burning, incineration, mechanical-biological treatment (MBT), composting and digestion is identical to the activity data needed to identify mitigation potentials and to estimate the effects of reducing, re-using or recycling of waste (see also Chapter 4). It can also be used for the reporting of air quality and inventories of pollutants. If inventory data can be used for other purposes like management decisions or the estimates of mitigation potentials, the benefits of inventory compilation increase. This is shown in the case of Chile, where the motivation for setting up a complete and reliable inventory increased with the use of inventory data for national policy development. The following Table 2-3 shows some countries in which inventory data is used for other purposes.

Table 2-2: National system and data availability

Country	Description
Bulgaria	A national inventory system for GHG emissions in Bulgaria was set up in 2003. It was established according to the country's Environmental Protection Act and the National Statistics Law. It is based on official agreements on the provision and exchange of statistical and environmental information between the National Statistical Institute of Bulgaria and the Ministry of Environment and Water Bulgaria. Further agreements to strengthen the institutional arrangements and to fulfil the required general and specific functions of the National Inventory System were signed in 2010 by the Ministry of Environment and the main data providers. As part of the Executive Environmental Agency, the Waste Monitoring Department collects information on waste management activities on an annual basis. The National Statistics Institute collects information on waste management activities by questionnaires. This information is processed by the Executive Environmental Agency and afterwards checked and adjusted by the National Statistics Institute and finally submitted to Eurostat (Bulgaria, 2015).
Ghana	Ghana started a process to involve more and new stakeholders in the data collection process, e.g. the Ghana Education Service for incineration data and the Ghana Health Service for biomedical waste data. The EPA developed a new questionnaire and included questions on activity data in existing questionnaires. The results are discussed with the stakeholders to ensure the improvement of data collection. A cooperation with the domestic statistical service is planned to close more data gaps. All data providers are invited to be part of working groups and workshops and to discuss improvements for the next GHG inventory (Ghana, 2015).
Indonesia	Activity data is available from the National Statistical Bureau that has branches in all cities in Indonesia. Data is collected regularly on an annual basis. Data provided by the National Statistical Bureau is used as activity data in the waste inventory. Some specific data on waste composition etc. is available from research projects initiated by the World Bank, GIZ and JICA (Indonesia, 2015).
Tunisia	The institutional structure for the national GHG inventory of Tunisia is already in place. As part of the International Climate Initiative of the German Ministry for the Environment, the current national inventory system of Tunisia has been analysed according to its strengths and weaknesses and an action plan has been implemented. Activity data needed for inventory compilation in the waste sector was already available at the ANGed and could be used for the inventory. Thus, the conditions to set up an inventory for the waste sector were good in Tunisia. (Tunisia, 2015).
Vietnam	A national inventory system has not yet been established in Vietnam and data from the waste companies is not free of charge. There are not many official statistics available that can be used in the waste sector. Only the provincial reports contain official information that are relevant for the waste inventory (Vietnam, 2015).

Source: Compilation by Öko-Institut

Table 2-3: Additional use of inventory data

Country	Description
Bulgaria	National waste data needs to be reported to Eurostat, a Directorate of the European Commission. This data is also used for the inventory (Bulgaria, 2015).
Chile	The principal objective of the GHG inventories has moved from reporting to policy advice. In the past the inventories were mainly prepared to comply with UNFCCC requirements. Recently the focus has shifted to providing a scientific basis for national policy development in the waste sector. This has led to higher requirements concerning completeness, accuracy and regional disaggregation (Chile, 2015).
Tunisia	Inventory results will be used for the development of NAMAs and can be very helpful for setting up new projects to receive further funding to tackle climate change (Tunisia, 2015).

Source: Compilation by Öko-Institut

2.3.2 QA/QC and uncertainties

Almost all countries have established Quality Assurance and Quality Control (QA/QC) procedures. These include checklists, use of automated software and voluntary review by third parties (see Table 2-4 Chile, Romania). Closely linked to such activities are uncertainty estimates; large uncertainties are trigger for more in-depth QA/QC activities. One important aspect is that the errors detected and the recommendations provided during these checks are acted upon. In minor cases (e.g. errors in units or transcription errors), corrections can be implemented directly; in other cases they should be documented and followed up in future inventory submissions (see Table 2-4 Ghana).

Table 2-4: QA/QC

Country	Description
Armenia	QA/QC procedures include multiple manual and automated checks of input data, parameter values and time series consistency. The IPCC inventory software with its automated checks provides another layer of QC. All data sources used for calculating emissions have been archived and listed. To ensure time series consistency, Armenia compares and analyses the estimates with previously made inventories (Armenia, 2014, p. 112).
Bulgaria	QA/QC focused on completeness and consistency of emission estimates and proper use of notation keys. Activities include QC checks for errors in input data and references, calculations, completeness, time series consistency and documentation (Bulgaria, 2014, p. 405).
Chile	Chile has included external experts in inventory development. They have helped to improve emission estimates, e.g. by providing expert opinion on the use of specific IPCC default parameters (Chile, 2015).
Ghana	The QA/QC process has two stages: 1. QC: Internal in working groups using formalized QA/QC Plans and documenting results. 2. QA: Carried out by third parties, e.g. academia, the UNFCCC, and by different sector experts. Can include recommendations to other agencies for improvements. Feedback is collected by the EPA and shared with the working groups (Ghana 2015).
Romania	A checklist is used to ensure that all quality control activities described in the QA/QC programme were performed (Romania, 2014, p. 708).
Namibia	Namibia has its own system for quality control of data being collected within the different institutions. All data are quality controlled at different stages until the final quality assurance is made by the Namibia Statistics Agency before archiving in national databases. The private sector also implements its own QA/QC during data collection and archiving (Namibia, 2014, p. 38).
South Africa	South Africa identified major sources of uncertainties, both random errors as well as a bias in the data and methodologies thanks to its QA/QC system. These include waste composition, incomplete activity data and the need for estimating emissions from solid wastes disposal separately for different climate zones (South Africa, 2009, p. 72, 74-75). Calculations with different waste generation rates were made to verify the generation rate (South Africa 2009, p. 76).
Tunisia	Uncertainties have been estimated for waste generation (60% uncertainty), quantities delivered to landfills (2% uncertainty of weighbridges), waste composition (20%-60% depending on landfill type) and the amount of methane flared (0.5%) (Tunisia, 2014).

Source: Compilation by Öko-Institut

2.4 Recommendations for general GHG inventory development

Institutionalisation

With the two year reporting cycle, it has become important for NAI countries to develop and agree processes to avoid 'starting from scratch' whenever an inventory is prepared. Together with adequate documentation of assumptions, data sources and calculations, this greatly facilitates inventory preparation for each BUR and National Communication.

Key categories and methodological choice

It is recommended that key category assessment is conducted and resources and efforts are dedicated to the categories identified as key. If possible, apply higher tiers in the categories identified as key.

Data collection and time series consistency

It is recommended that IPCC methodologies are used to gap-fill missing data. If different data sets are combined, ensure time series consistency in the transition from one source to the other.

QA/QC

Improving the quality of the inventory should be seen as a continuous process. A QA/QC plan should be developed and implemented. Any issues and recommendations identified either during inventory preparation or during the QA/QC activities should be compiled in an inventory improvement plan if they cannot be implemented directly. At the start of a new inventory cycle, the improvement plan should be reviewed and points to be included should be identified.

3. GHG inventories in the waste sector

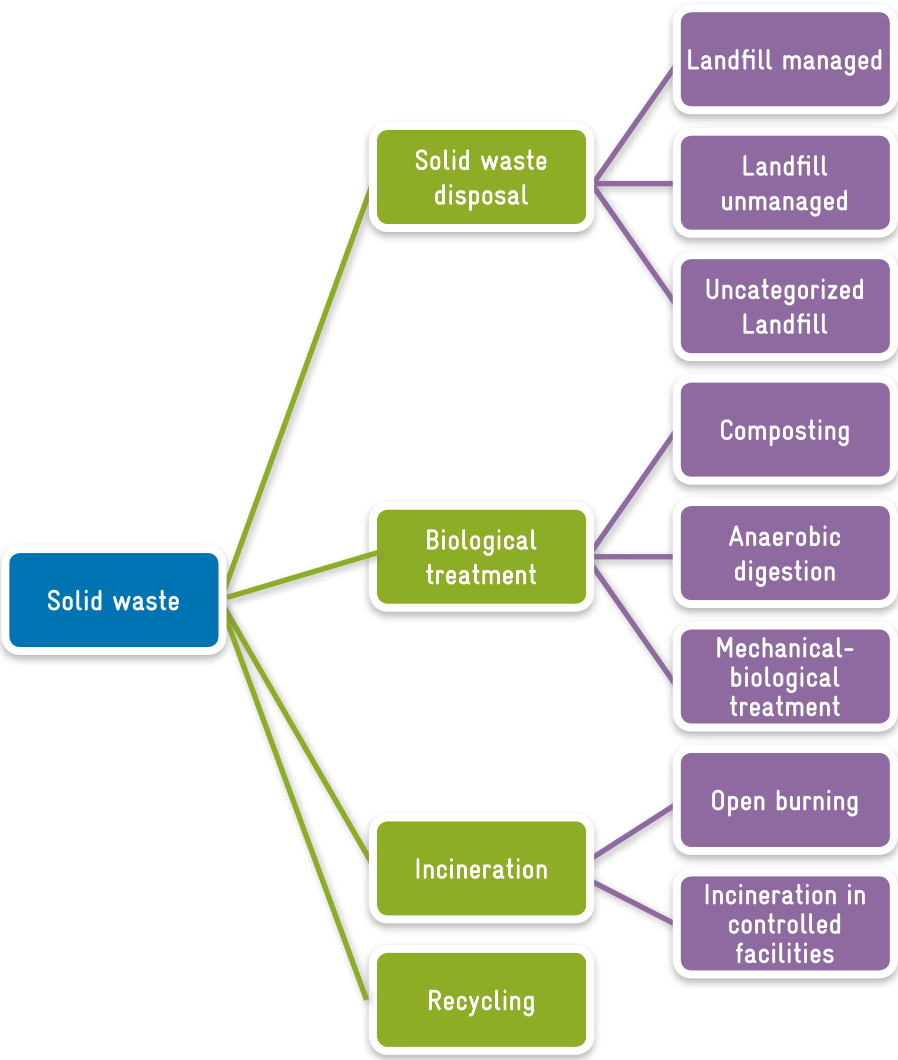
GHG emissions are generated from the treatment and disposal of liquid and solid waste. These emissions need to be reported along with those of other sectors within BURs and National Communications to the UNFCCC. Methodologies and guidance are provided in the IPCC Guidelines. According to the 2006 IPCC Guidelines, the emission estimates in the waste sector need to be carried out for four sub-categories:

1. solid waste disposal;
2. biological treatment of solid waste;
3. incineration and open burning; and
4. wastewater treatment and discharge.

The compilation of a GHG inventory in the waste sector requires the availability of sometimes complex activity data that comes from different actors and stakeholders or from national statistics.

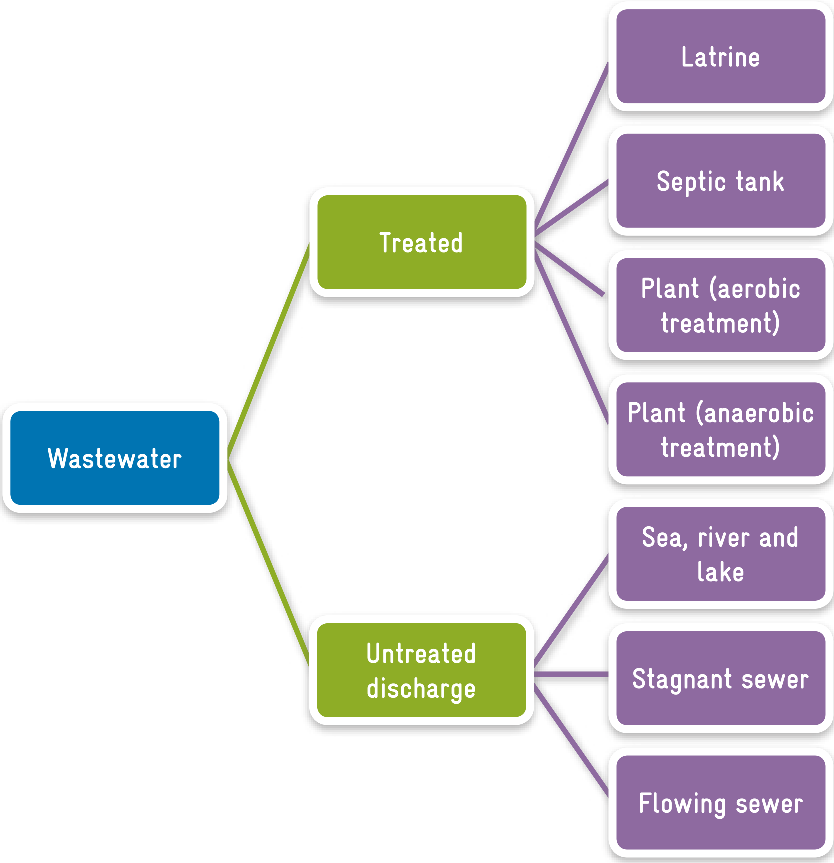
Of the above, the first three categories mainly refer to possible routes for treatment and disposal of solid waste. An overview of pathways is shown in Figure 3-1, below.

Figure 3-1: Possible treatment and disposal routes of Solid Waste



Source: Compilation by GIZ

Figure 3-2: Possible treatment and disposal routes of Wastewater



Source: Compilation by Öko-Institut

In the case of the fourth category, wastewater treatment and discharge, different paths exist, according to whether wastewater is treated or just discharged to the environment or sewers without any treatment. Figure 3-2 provides an overview of the treatment and discharge options for wastewater.

The information provided in the following subchapters (3.1 - 3.4) is based on the guidance provided in the IPCC 2006 Guidelines and complemented by examples from some selected countries' National Communications, first Biennial Update Reports and other national documents (see Annex II).

All sub-chapters follow the same structure: an overview of the source category is given followed by a description of methodological issues, such as those related to the choice of method, the choice of activity data and data sources, emission factors and its applicability and other characteristics of the category based on the 2006 IPCC Guidelines. Subsequently, examples and problems encountered from various selected countries are provided. These examples have been selected to show different possible approaches on how to best report on GHG emissions from the sector with a limited amount of national data and other information. These approaches might orient other countries facing similar problems. They are mainly based on Non-Annex I Parties experience but some information from Annex I countries has been included. Each subchapter concludes with a set of recommendations for the inventory development of the sub-category.

3.1 Solid waste disposal

3.1.1 Overview

The disposal of solid waste including municipal waste, industrial waste, sludge and other solid waste on solid waste disposal sites (SWDS), commonly known as landfills, produces methane emissions (CH_4) and carbon dioxide emissions (CO_2). Nitrous oxide emissions (N_2O) also occur to a small extent but are not significant. Methane is produced by the anaerobic microbial decomposition of organic matter in SWDS over time. A main driving force of CH_4 emissions from waste disposal on land is the amount of biodegradable waste such as food waste, garden waste or wood heading to landfills. If the waste that is landfilled is not compacted properly, the decomposition of organic material from biodegradable waste will release CO_2 emissions as it takes place under aerobic conditions, as compared to CH_4 (see Box 2). According to the IPCC Guidelines, the CO_2 emissions are not accounted for in the national GHG emission totals as they are of biogenic origin.9 The emissions related to their production are included under the Agriculture, Forestry and Other Land Use (AFOLU) sector.

Emissions from solid waste disposal are relatively low but they have risen continuously in developing countries due to changing production and consumption patterns and growing population. The amount of total waste generation is strongly related to the population numbers and can be determined on the basis of waste generation rate per capita10.

To estimate the CH_4 emissions arising from solid waste disposal, the following steps need to be followed:

1. The population numbers of the country need to be determined for the last 50 years,
2. Waste generation rates in kg/cap need to be estimated for these years,
3. The share of total solid waste deposited in waste disposal sites needs to be estimated,
4. The share of the different types of waste disposal sites (managed/unmanaged) needs to be determined,
5. The waste composition of the waste landfilled needs to be estimated.

In most NAI countries there is a strong difference between the living standards in rural and urban areas. This has very large effects on consumption patterns, infrastructure and affects the whole waste sector; waste generation rates, waste collections systems, waste disposal, waste treatment and waste composition may differ largely between urban and rural areas in a country and might need to be estimated separately.

The basis for management decisions in the waste sector are activity data as collected for the inventory compilation. The amount of generated waste per capita in relation to projections on population and the share of waste disposed can indicate the size and number of landfills needed, whereas the knowledge on the waste composition can be used for setting up recycling strategies, potentials for biogas generation or increased composting.

Box 2: Aerobic and anaerobic decomposition

Microbial decomposition of organic material can take place under aerobic or anaerobic conditions. Under aerobic conditions, i.e. if sufficient oxygen is present, the degradable carbon is oxidized to CO_2. If the carbon comes from organic sources (e.g. food waste or sewage) the CO_2 emissions are of biological origin and are not included in the national GHG emission totals. Aerobic conditions typically occur in shallow solid waste disposal sites (SWDS) which have not been compacted, in shallow ponds or during composting. In contrast during anaerobic decomposition no oxygen is present and the carbon will be converted to methane (CH_4). This typically occurs in compacted and/or deep landfills, in deep ponds and during anaerobic digestion. In most cases both aerobic and anaerobic decomposition take place in parallel in different layers or pockets of a landfill, ponds or other treatment site.

3.1.2 General methodological considerations

According to the 2006 IPCC Guidelines, the estimation of emissions from solid waste disposal sites (SWDS) should be based on the First Order Decay (FOD) method. The method accounts for the fact that the degradable organic components decay slowly over decades. Food waste or wood does not completely decompose in the year in which it is landfilled, but rather has a maturing period ranging from one year for the more labile components to over 35 years for those with the lowest biodegradation rates. FOD is based on the premise that CH_4 production is solely dependent on the amount of organic matter remaining in the waste body. In the first years when the amount of carbon remaining in the waste is highest, the CH_4 emissions are higher and then decline. According to the IPCC Guidelines, it is good practice to estimate CH_4 emissions from solid waste disposal for a period of at least 50 years. This ensures that all carbon included in the waste disposed is decomposed and related emissions are estimated in the year in which they occur.

9 Plants and trees bind CO_2 from the air, as they need this for photosynthesis. According to the IPCC Guidelines the same amount of CO_2 that is used by the plants will be released againduring decomposition under aerobic conditions. Thus this amount of CO_2 is not accounted for as GHG emissions in the national totals, as it has been stored by the plants while growing. Emissions from deforestation and land conversion are reported under Agriculture, Forestry and Other Land Use (AFOLU).

10 Waste generation rates are usually influenced by consumerism linked to GDP growth, use of packaging materials in the country and incentive/disincentive policies governing waste avoidance.

Emission estimates can be carried out according to three different tier methods that determine the level of detail and the use of default values. All tier methods provided in the 2006 IPCC Guidelines include the application of the FOD methodology. For Tier 1 default activity data and default parameters can be applied11. Tier 2 applies default parameters but requires national activity data on current and historic waste disposal. Historic data needs to be country-specific for at least the last 10 years. The Tier 3 method includes good quality country-specific activity data and nationally developed key parameters or measurement derived country-specific parameters.

The 2006 IPCC Guidelines provide an Excel model12 that includes country- and region- specific default activity data and parameters that are applicable to a calculation according to the Tier 1 method (see Chapter 5.2). The model can be applied with very limited additional data for Tier 1; it can also be used to estimate emissions using higher tiers.

In the 1996 IPCC Guidelines and the 2000 Good Practice Guidelines, the so-called mass balance method could be applied as a Tier 1 method to calculate emissions from solid waste disposal. According to the mass balance method, all emissions occur in the same year in which the waste is disposed, not taking into account the slow decomposition of the organic material over years. This leads to "correct" results if waste generation and treatment practices remain constant over decades. In the case of NAI countries for which the population and the amount of generated and disposed waste are increasing, the application of this method generally leads to an overestimation of emissions as solid waste disposal was lower in historic years. Applying this method for countries that experienced a reduction of waste landfilled and an increase of recycling, composting and landfill gas recovery, the GHG emissions would be underestimated. For calculations using the mass balance method, activity data is only required for the year of calculation.

In comparison to the 1996 IPCC Guidelines, considerably improved default data was used in the 2006 Guidelines, and default activity data was provided for more countries and regions. The use of the mass balance approach is no longer deemed good practice in most circumstances.

3.1.3 Compilation of activity data

The 2006 IPCC Guidelines provide default data on country- or region-specific levels. As a starting point, starting a GHG inventory for the waste sector using default data if limited national statistics and resources are available is a good basis; nevertheless, collecting country-specific activity data will make the calculation of emissions from solid waste disposal more accurate. In most cases having national activity data on waste generation is also the basis for data on biological treatment, incineration and open burning of waste.

Activity data needed to estimate CH_4 emissions from solid waste disposal include: population data, waste generation rates, waste composition as well as information on the amount of waste landfilled and the type of waste disposal sites. Historical data for about 50 years on all these parameters is ideally needed for estimating emissions using the First Order Decay method.

For calculating CH_4 emissions from solid waste disposal, the first step is to check which data sources are available and can be used:

1. Are national statistics available on waste generation, waste disposal and waste composition? For which time period? Does a periodical update of the data occur?
2. Are research studies available on waste generation, waste disposal, and waste composition? For which years?
3. Which experts are available that can be approached and whose assumptions can be used?

If there are no sources for activity data available, IPCC default values may be used. Alternatively, the country or region can collect its own activity data for the purpose of inventory preparation if sufficient resources are available. The 2006 IPCC Guidelines include guidance and information on activity data collection. Field samples and questionnaires are common methods for collecting activity data in the waste sector.

11 Default activity data and default emission factors or other default parameters are collected from different studies by literature reviews and included in the IPCC Guidelines to ensure that each country is able to calculate emissions for each category. If no country specific data is available countries should use the default value provided in the IPCC Guidelines for the country or the region the country is located or apply the default value of a country that is nearby and has similar conditions.

12 http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

3.1.3.1 Waste generation

a) Municipal solid waste generation

Overview

Waste generation differs widely between countries and sub-national units as they depend on consumption and production patterns. With increasing living standards, the amount of generated waste increases as well. The total waste generation is the basis for activity data that is used for the calculation of solid waste disposal, biological treatment of solid waste and incineration and open burning.

Methodological issues

According to the 2006 IPCC Guidelines, the amount of municipal solid waste (MSW) generated is estimated on the basis of population numbers and a generation rate of waste per capita in kg/cap/year. MSW generally includes household waste, garden and park waste as well as commercial/institutional waste. Regional default values for waste generation per capita are provided in the 2006 IPCC Guidelines (Vol. 5, Ch. 2, Table 2.1). Available default data for waste generation is based on studies from the late 1990ies and early 2000s; they are applicable for the more recent years. For establishing a time series for historic years, the IPCC Guidelines suggest adapting waste generation rates per capita using extrapolation or interpolation methods or other drivers such as urban population or economic indicators.

The Guidelines suggest using national population statistics or – if these are not available – international databases, such as UN data for population numbers (see Annex II). If waste is collected only from the urban population, only the urban population should be used for the emission estimates.

Good Practice country examples

Estimating waste generation differs among population groups in many NAI countries. Given the differences in the economic situation and lifestyles that affect the waste generation rates, some countries divide population data used for emission estimates from SWDS into urban and rural population (see Table 3-1 Tunisia), while others separate population data into high income and low income urban population (see Table 3-1 Namibia). The following Table 3-1 presents an overview of the disaggregation, use of population data and other data according to climatic zones and the split into rural and urban areas.

Population is estimated either by national statistics available in many countries or by the use of UN statistics (see Table 3-1) but most countries lack information on the total amount of waste generated in the country, especially along the time series. In practice, countries apply different approaches to estimate the total waste generation, depending on data availability and the circumstances in the country. An adaptation along the time series is applied in many countries.

The effect of increased living standards in relation to higher waste generation rates is reflected in the low historic waste generation rates used by Tunisia and Vietnam, including the use of different waste generation rates for urban and rural areas. Common practice applied by Bulgaria and India is the estimation of waste generation rate proportional to urban population or in relation to economic factors as applied in Namibia and South Africa.

Table 3-2 shows some examples of how countries are estimating their waste generation rates for the whole time series.

Table 3.1: Examples of the disaggregation of population statistics and other data

Country	Description
Chile	National figures were disaggregated into climatic macro zones to identify different waste degradation conditions. The Northern Zone is classified as "boreal and dry temperate" and the Southern Zone is classified as "boreal and wet temperate" (Chile, 2014b, p. 141).
Namibia	Population data is split into "high income" and "low income" urban regions for 2010. The need for this categorization was prompted by the sustained and significant population migration from rural to urban regions with the emergence of fast-expanding suburbs to the main cities in which the dwellers' lifestyle is urban with a relatively lower purchasing power (Namibia, 2014, p. 87).
Tunisia	Population data are available from 1950 onwards from Tunisia's National Statistics Institute. A distinction is made between the rural and urban population and different generation rates are applied (Tunisia, 2014).
South Africa	Population data for South Africa is taken from the UN statistics, as national population data is not consistent throughout the time series. The UN estimates were found to be more suitable than the Statistics South Africa values as they consistently covered the entire period under investigation. The data from Statistics SA is insufficient because it is only representative of the country's demographics from the 1996 census onwards (South Africa, 2009, p. 72).

Source: Compilation by Öko-Institut

Table 3-2: Examples of estimating waste generation rates in different countries

Country	Description
Bulgaria	Historical waste generation for 1950-1978 was calculated based on the proportion of urban population. From 1979 to 1993 data on waste generated are compiled by the waste collectors serving settlements. Statistical data on waste generation is available from 1999-2010 onwards. Missing years (1994-1999) are calculated by single regression methods based on actual data (Bulgaria, 2015).
Brazil	Solid waste generation rate per capita is calculated based on data from two different waste management companies. Data from one is used to estimate the quantities of waste landfilled in 1970 and data from the other for waste landfilled in 2005. Data for the intermediate years were linearly interpolated (Brazil, 2010, p. 241).
India	According to studies from India's National Environmental Engineering Research Institute, there is a wide variation in per capita waste generation. The average value (0.55 kg/capita/day) of these quantities was used for calculations. The value is close to the average regional value for South Central Asia. As no waste generation data is available for the last 50 years, waste quantities of historic years is only proportional to urban population (India, 2012, p. 75).
Namibia	Estimates of solid waste generation for rural regions for 2010 were subsequently developed. This was done by discounting solid wastes, which are typically generated by urban dwellers from data available on waste characterization from landfills. Using the 2010 baseline, population census data and adjusted for socio-economic factors, estimates for solid waste generation were then conducted for the period of 1990 to 2009 (Namibia, 2014, p. 88).
Tunisia	GDP growth is used as an indicator for the development of waste generation rates along the time series. The per capita waste generation rate for 1990 is available in a UNDP study (0.5 kg/cap/day average of the urban and rural population). The 2005 generation rate of 1.3 kg/cap/day for urban areas is available in a study by the National Agency for Waste Management (ANGed). The waste generation rate in 1950 is assumed to be 0.2 kg/cap/day in urban areas and 0.1 kg/cap/day in rural areas. (Tunisia, 2014)).
South Africa	Total waste generation rate for South Africa in 1990 was assumed to be 318 kg/cap/yr. After careful examination of the generation rates and the disparities of generation rates per province this amount was deemed to be too low.The estimated 318 kg/cap/yr was presumed to be more representative if it were related to the organic fraction of MSW only and not presenting the whole waste generation rate per capita. Using this estimate with 1990 as the base year, the MSW quantities generated and disposed of in landfills were calculated for the period of 1950 to 2000. For these computations the following assumptions were made: Firstly, the waste growth rate from 1990 to 2000 was assumed to follow GDP growth. Secondly, a lower waste growth rate was assumed for the earlier period (2% for the period of 1950 to 1960 and 1% for the period of 1961 to 1989). (South Africa, 2009, p. 72, 74-75).
Vietnam	Data on total waste generation in urban areas is available from 2004 onwards. For provinces in which total waste generation is not available for all years from 2004 onwards, an annual growth rate of waste generation of 10% is assumed. The waste generation rate before 2004 (1990-2003) is estimated by using waste generation of 0.7 kg/person/day in urban areas and a waste generation rate of 0.3 kg/cap/day in rural areas (Vietnam, 2014, p. 221).

Source: Compilation by Öko-Institut

b) Industrial waste generation

Overview

Industrial waste that is landfilled can include very diverse components, inter alia organic materials, plastics, paper as well as construction and demolition waste. For the GHG inventory in the waste sector, only industrial waste that contains DOC or fossil carbon needs to be reported (e.g. wood or plastics). In most NAI countries industrial waste is included under MSW as there is no separation between industrial and municipal waste.

Methodological issues

Some default activity data on industrial waste generation is available in Table 2.1 and Table 2A.1 (Vol. 5, Ch. 2, waste data) of the 2006 IPCC Guidelines. There is no default data available for NAI countries except for some Asian countries. The IPCC Guidelines suggest applying default data from countries with similar circumstances if no national activity data is available.

Good Practice country examples

Information on industrial waste is provided by Indonesia and Tunisia (see Table 3-3). Activity data on industrial waste generation is correlated to production rates in Indonesia. Tunisia calculates the amount of industrial waste proportional to GDP development.

Table 3-3: Information on industrial waste

Country	Description
Namibia	The amount of sludge generated per capita for 2010 was estimated using that year's data for Windhoek City Council. Using this factor and urban population, the amount of sludge generated for the period of 1990 to 2009 was then estimated for the other urban areas (Namibia, 2014, p. 88).
Tunisia	Sewage sludge has historically been dumped in landfills. The evolution of sludge generation is indexed to the population connected to a wastewater treatment plant (Tunisia, 2014).

Source: Compilation by Öko-Institut

c) Sludge disposal on landfills

Overview

Some countries dispose of sludge from domestic and industrial wastewater plants in landfills. The amount of sludge from domestic wastewater might be included under municipal waste or sludge from industrial wastewater may be included under industrial waste. If sludge is not disposed of in landfills, it can be composted or incinerated. In some countries sludge is also used as organic fertilizer and applied to agricultural land. Double counting needs to be avoided by reporting a consistent amount of sludge that is disposed of on SWDS; only sludge that goes along with solid waste has to be accounted under this category. All other sludge that is composted, incinerated, treated in wastewater plants or applied to agricultural land should be accounted under other categories.

Methodological issues

There is no IPCC default activity data available. If no country-specific activity data is available on the amount of sludge that is disposed of, composted, incinerated or spread on agricultural land, all emissions from sludge are included under wastewater treatment.

Good Practice country examples

Namibia and Tunisia provide relevant information on the estimation of activity data for sludge disposal in landfills (see Table 3-4). In Tunisia the amount of sludge disposed of in landfills is calculated proportional to the population connected to wastewater treatment plants.

3.1.3.2 Share of solid waste landfilled

Overview

Total waste generated does not equal the amount of total waste landfilled. Along the waste stream waste is collected, parts of the collected waste is recycled, other parts may be composted or incinerated or dumped in the landscape and the remaining waste is landfilled. Due to inadequate collection systems, waste collection rates are very low in most NAI countries, especially in rural areas, and open burning of waste that is not collected is a common practice. Due to developments of waste policies, improvements in the collection system and infrastructure the share of waste disposed of in landfills and thereby emissions from SWDS can increase over the time series. Recycling, composting, methane recovery and waste-to-energy are policies that led to a decrease of waste disposal on landfills and/or reduce GHG emissions.

The data on the fraction of solid waste disposed may be obtained from a national waste stream analysis as suggested by IPCC (2006 IPCC, Vol. 5, Box 2.1, pp. 2.6-2.7). Although this exercise is already of a higher tier, having this picture supports country-level confidence in data.

Methodological issues

Default data on the share of waste landfilled is available in Table 2.1 and Table 2A.1 of the 2006 Guidelines (IPCC, 2006). No further information on the share of waste landfilled is provided.

Table 3-4: Information on activity data for sludge

Country	Description
Namibia	The amount of sludge generated per capita for 2010 was estimated using that year's data for Windhoek City Council. Using this factor and urban population, the amount of sludge generated for the period of 1990 to 2009 was then estimated for the other urban areas (Namibia, 2014, p. 88).
Tunisia	Sewage sludge has historically been dumped in landfills. The evolution of sludge generation is indexed to the population connected to a wastewater treatment plant (Tunisia, 2014).

Source: Compilation by Öko-Institut

Good Practice country examples

The amount of waste disposal is closely correlated to the amount of waste collected (e.g. Romania, Vietnam, see Table 3-5). In Bulgaria and Kazakhstan the share of waste landfilled is almost 100%, while increased recycling rates decrease the share of waste landfilled. Vietnam applies a lower share in historic years that increases every year by a certain percentage. Different shares for waste disposals are applied for rural and urban areas, given a higher share in urban areas (see Indonesia and Vietnam). The following Table 3-5 presents an overview of how different countries have made assumptions on the share of waste landfilled.

3.1.3.3 Type of waste disposal sites (landfill managed/ unmanaged)

Overview

The characteristics of waste disposal sites are very different, depending on the control, the placement and the management of the waste. In small uncontrolled rubbish pits or road dumping sites, waste is disposed without any management, whereas in managed landfills waste is compacted and covered after it is disposed. Deep and compacted landfills have the highest CH_4 emissions, as waste decomposes under anaerobic conditions. In shallow and unmanaged landfills the waste is loosely stored and might decompose aerobic as enough oxygen is available (see also Box 2, page 17). The management practices

Table 3-5: Information on the share of waste landfilled in different countries

Country	Description
Bulgaria	Historically nearly all of the generated waste has been landfilled (95%-97%), as there have been no recycling systems in place. Separate collection and recycling of household waste began in 1990. Due to increased recycling the share of waste landfilled decreased to approximately 79% of MSW generated in the country in 2012 (Bulgaria, 2014, p. 394; Bulgaria 2015).
Chile	Existing data was incomplete and of low quality. Together with an expert on statistical methodologies for gap filling and time series consistency, waste disposal data was compiled for all years since 2000. For prior years the 2000 waste generation and disposal rates were used and multiplied with actual population statistics (Chile, 2015).
Indonesia	According to Indonesian official Statistics in urban areas almost 60% of waste is taken to solid waste disposal sites while in rural areas or small cities this figure is only 30% (Indonesia, 2010, p. II-26).
Kazakhstan	About 97% of solid waste is placed in landfills for disposal and only 3% is recycled (Kazakhstan, 2014)
Mexico	Default IPCC data on the share of waste landfilled is used for the period from 1950 to 1989. Since 1990 country-specific activity data is available and has been utilised (Mexico, 2012, p.X-168).
Romania	From 2006-2011 the percentage of MSW collected from total MSW generated ranged between 77% and 86%. From the total amount of MSW collected in 2011, 88% was deposited. It is assumed that the other 12% are generally recovered, reused and/ or composted in households (Romania, 2014, p. 70).
Tunisia	The amount of household waste, industrial and medical waste disposed of in landfills since 1950 is estimated on the basis of national data. Domestic waste, industrial waste, medical waste and sewage sludge have historically been landfilled. The share of this waste has increased over the period mainly due to economic development and waste policy. The amount of "other" waste landfilled is estimated based on the results of a diagnostic study and the determination of the characteristics of wild dumpsites (uncontrolled landfills) conducted by ANGed in 2005. Experts believe that part of the waste of the rural population is burned. This amount, which corresponds to 12% of the waste generated by the rural population (this fraction is considered constant over the entire period), is subtracted from the quantities stored (Tunisia, 2014).
South Africa	The estimate of the share of waste landfilled is based on the assumption that the urban population of the country has good access to well-managed solid waste dumping sites (South Africa, 2009, p.96).
Vietnam	There is a close correlation between waste collection and waste disposal; waste that is collected is usually taken to landfills. The ratio of the share landfilled is based on the collection ratio and was assumed to be 20% in the year 1990 and 40% in the year 2000 in rural areas. For urban areas the share of waste disposal in 1990 is 45%. An annual increase of 2% is applied to urban and rural waste disposal shares for historic years. Data on the most recent years is available from the 2011 Environmental Report. For industrial solid waste, the activity data was collected from 5 years of environmental status reports from each province. As the amount of industrial solid waste disposed in landfill sites from 1990 to 2005 is not available, annual change of MSW in the same period is applied for estimation (Vietnam, 2014, p. 222).

Source: Compilation by Öko-Institut

of waste disposal sites have changed over time. Whereas in historic years most waste went to shallow unmanaged waste disposal sites, due to missing regulations and collection systems, managed landfills have been opened or waste has been landfilled in deeper unmanaged disposal sites in more recent years due to increased population and waste generation. Some countries have also set up their own regulations that define which landfill is managed and which is unmanaged. For example, for EU Member States the Directive 1999/31/EC on the landfill of waste defines the requirements for managed landfills.

Methodological issues

The amount of methane produced depends on the characteristics of the landfill, as unmanaged shallow landfills produce less CH_4 than managed landfills because the organic fractions of the waste decompose under aerobic conditions. For calculating CH_4 emissions of solid waste disposal, the Methane Correction Factor (MCF) reflects the way in which MSW is managed and the effect of management practices on CH_4 generation as explained in Section 3.1.4. To apply the MCF, the share of waste disposed of at different types of waste disposal sites needs to be available.

The 2006 Guidelines define four different types of waste disposal sites and include the category of "uncategorized landfills" as a fifth option:

1. Anaerobic managed solid waste disposal sites: These must have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste.
2. Semi-aerobic managed solid waste disposal sites: These must have controlled placement of waste and will include all of the following structures for introducing air to waste layer: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system.
3. Unmanaged solid waste disposal sites – deep and/or with high water table: All SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 metres and/or high water table at near ground level. Latter situation corresponds to filling of inland waters such as ponds, rivers or wetlands with waste.
4. Unmanaged shallow solid waste disposal sites; all SWDS not meeting the criteria of managed SWDS and which have a depth of less than 5 metres.
5. Uncategorised solid waste disposal sites: only if countries cannot assign their SWDS to the four categories of managed and unmanaged SWDS above can the MCF be used for this category.

The 2006 IPCC Guidelines do not provide country- or region-specific default data for the share of waste disposed in one of the four waste disposal categories.

Good Practice country examples

Estimates of the disposal of waste according to the four categories are available from inventories or statistics in Armenia and Kazakhstan. They use available data on managed landfills for large cities and group all landfills that are located in small cities or settlements as unmanaged. Surveys or expert judgement are used to set up estimates of the share of waste disposed in different landfill sites in Bulgaria. Tunisia measures the amount of waste disposed of in managed landfills and subtracts this amount from the total waste landfilled. To reflect the development of waste disposal sites, China divided the long time series into four periods for which differences in the management of the sites have been identified. Mexico provides information on the use of activity data along the time series (see Table 3-6).

3.1.3.4 Waste composition

Overview

Additionally to waste generation and waste management practices, to calculate CH_4 emissions, it is important to know the composition of the waste disposed, since only those residues with a carbon fraction will contribute to CH_4 emissions. Metal or glass does not contain carbon; plastics or electronic waste contain fossil carbon but this is hardly degradable. Fractions with large degradable organic carbon content such as paper or food waste will contribute the most to the CH_4 emissions from solid waste disposal. Thus, the amount of CH_4 emissions is very sensitive to the size of the fraction that is inert or hardly degradable.

The variability in waste composition is very high, depending on consumption patterns, recycling rates, size of settlements and distance to cities. It also changes throughout the year in the same city; reliable data on waste composition is hardly available, especially for the long time series beginning in 1960.

Table 3-6: Assumptions on the share of waste disposal in different countries according to the four disposal categories

Country	Description
Armenia	Activity data on the share of waste disposal to the different categories has been collected from inventory results of solid waste disposal sites/landfills operating over the period of 1990-2012. Based on urban population data and information on cities/ towns and urban settlements the following classification is used: * The capital city of Yerevan. Anaerobic managed solid waste disposal sites ("Nubarashen" SWDS - the largest in the country); * Cities of Gyumri and Vanadzor. Unmanaged solid waste disposal sites – deep and/or with high water table. * 45 additional cities and towns of the country. Unmanaged shallow solid waste disposal sites (Armenia, 2014, p. 108).
Bulgaria	For the period of 2003-2011 the data on the amounts of MSW disposed on managed and unmanaged SWDS were provided by the Waste Directorate from Bulgaria's National Environmental Protection Agency, as a result of surveys conducted each year. To determine the quantity of managed and unmanaged landfills on the national level, expert judgments and assessments are made by leading experts in the field of waste (Bulgaria, 2014). The main criteria for managed landfills are the requirements laid down in the EU Directive on the landfill of waste. All landfills before 2000 are assumed to be unmanaged (Bulgaria, 2015).
Chile	The percentage of solid household waste sent to SWDS was obtained from the regional offices of Chile's Ministry of the Environment, which reported on respective regions. The quantity of waste disposed of in each municipality was used to calculate the percentage of waste disposed of in each kind of waste facility. Where gaps existed in the data this information was extrapolated and compared against the information contained in the "ECOAMERICA, 2012" inventory. In 2010, 70% of all MSW was disposed of in sanitary landfills, 22.7% was taken to unmanaged landfills, and 7.3% ended up in garbage dumps (Chile, 2014b, p. 142).
China	The 1956-2005 timeframe is divided into four periods for which differences in the management of waste treatment sites have been identified. When calculating the Methane Correction Factors (MCF), the differences in city sizes and regional economic development levels are considered (China, 2012, p. 67).
Indonesia	The SWDS in most big cities in Indonesia are considered to be unmanaged SWDS because they are simply open dumps; within the context of GHG emissions, they are categorized as unmanaged deep (>5 m) waste (Indonesia, 2010, p. Vv-32).
Kazakhstan	In rural areas, waste is placed on unmanaged waste dumps and decomposed aerobically; no methane generation occurs. Landfills near large cities meet almost all the requirements for disposal of solid waste: waste is placed in layers, in a controlled way, in a certain place. All landfills located in and around the cities Almaty and Astana are identified as managed landfills, whereas all landfills in other cities are defined as unmanaged shallow solid waste disposal sites. (Kazakhstan, 2014, pp. 292).
Mexico	100% of waste is disposed of in uncategorized landfills from 1950 to 1989. For 1990 onwards, country-specific activity data is available. In 2010 a share of 62% of waste is landfilled in anaerobic managed solid waste disposal sites, 8% are disposed of in semi-aerobic managed solid waste disposal sites and the rest of 29% are distributed to uncategorized landfills (Mexico, 2012, p. X-167).
Namibia	There are three managed landfill sites in Namibia: one at Kupferberg in the Khomas region for the disposal of general and hazardous waste generated within the City of Windhoek; and two in the region of Erongo, which receive waste from Swakop-mund and Walvis Bay. The remaining collected solid waste is disposed of in open dump sites (Namibia, 2014, p. 86).
Romania	In Romania MSW is disposed of in managed and unmanaged SWDS. In accordance with European regulations, the number of unmanaged SWDS has decreased in recent years. In accordance with European regulations, the unmanaged SWDS are subject to a transition period and are being gradually phased out up to 2017 (Romania, 2014, p. 707).
Tunisia	The distribution of the quantities landfilled by type of discharge (controlled/ uncontrolled) is performed on the basis of knowledge of the quantities entering managed landfills (weighing at site entrance). In these landfills, waste is deposited and compacted. Once filled, it is equipped with a collection system and covered. The landfill is therefore anaerobic. The difference between the total amount of waste generated and the amount measured on managed landfills is attributed to uncontrolled landfills. The first managed landfill opened in 1999. By 2010 ten landfills opened in Tunisia which receive more than 85% of the stored waste annually. The distribution of the quantities disposed of in non-controlled deep discharge (lower or higher than 5 meters) is performed on the basis of a study by ANGed. This study of twenty dumps has calculated that 68% of waste disposed of in landfills in 2005 is less than 5 meters deep. Unable to determine this parameter more accurately, this value is applied to the entire time series (Tunisia, 2014).
South Africa	In the 2000 inventory, only greenhouse gases generated from managed landfills are included for two main reasons: Firstly, data on waste dumped in unmanaged and uncategorised disposal sites have not been documented. Secondly, most of the unmanaged and uncategorised disposal sites are scattered throughout rural and semi-urban areas across South Africa and are generally shallow (i.e. less than 5 metres in depth). In such shallow sites a large fraction of the organic waste decompos-es aerobically which means methane emissions are insignificant compared to those from managed landfill sites (South Africa, 2009, p. 68).
Vietnam	Based on expert judgments the share of "unmanaged – deep" is 40%, "unmanaged – shallow" is 50 %, "managed – anaerobic" is 5% and "managed – semi-aerobic" is 5% (Vietnam, 2014, p. 224).

Source: Compilation by Öko-Institut

Table 3-7: Assumptions on waste composition in selected countries

Country	Description
Armenia	The results of the composition of the largest landfill in Armenia have been generalized. There is more data from other landfills available and also results of studies on the methane capture potential have been used. Based on this information a DOC parameter for the time series of 1990-2012 has been developed. During the last decade, there has been an increase in the SW fraction containing degradable organic carbon (e.g. food waste, paper, cardboard) (Armenia, 2014, p. 107).
Bulgaria	Waste composition is based on a study conducted in 2002 that determines the shares of different waste types depending on the geographical distribution and population size of different settlements. A model has been developed, which calculates different fractions of the biodegradable organic content of waste for different population groups according to the size of settlements (Bulgaria, 2014, p. 400).
India	There are several studies on quantity and composition of waste available. The average composition data of the waste has been used in the estimation of DOC (India, 2012, p 75).
Mexico	Default IPCC data on waste composition is used from 1950 to 1989. Country-specific activity data is available for 1990 onwards (Mexico, 2012, p. X-168).
Romania	A large amount of recyclable materials (paper, cardboard, glass, plastics, metals) is not recovered but is finally stored together with other municipal wastes. The percentage of biodegradable waste in deposited waste is 63% for the year 2011. Historical data on waste composition is based on a research study (Romania, 2014, p. 708).
South Africa	The estimations are based on bulk waste[13] because there is no waste composition data for the period under study (1990-2000). Data on waste composition in South Africa varies considerably and is also very limited. The data that is accessible comes from a small number of municipalities and covers only certain years. There is no data dating back to the 1950s showing how waste composition has changed annually nor how this relates to urban income disparities and population densities (South Africa, 2009, p. 71).
Tunisia	The composition of the waste comes from a study conducted in 2007 (feasibility study for the construction of a second landfill for the Greater Tunis, ANGed). This composition is also verified in the context of CDM projects on landfills (Tunisia, 2014).

Source: Compilation by Öko-Institut

Methodological issues

The waste disposed of in landfills belong to different waste fractions that can be grouped according to the amount of carbon included:

- Waste types with high degradable organic carbon (DOC) content: Food waste, garden and park waste, paper and cardboard, wood, textiles;
- Waste types with small amount or hardly degradable amount of non-fossil carbon: Ash, dust, rubber and leather;
- Inert waste with only fossil carbon or no carbon contents: Plastics, metal and glass, electronic waste.

To estimate emissions from solid waste disposal, the share of food, garden residues, paper, wood, textiles and nappies in the total amount of waste landfilled needs to be available.

The 2006 Guidelines provide default data on waste composition for 19 regions (IPCC, 2006). The default data is based on research studies on waste composition in the 1990s and the early 2000s.

Good Practice country examples

Table 3-7 presents an overview of how selected countries have made assumptions on their national waste composition. Data on waste composition is based on research studies in many countries (see Table 3-7, Bulgaria, India, Romania, Tunisia). This data has been generalized and applied to the total amount of MSW landfilled. Mexico uses IPCC default data for historic years and applies country-specific data since they are available. Bulgaria calculates waste composition on the basis of the size of settlements. This assumes that the consumption patterns in large settlements are very different to the consumption patterns in small settlements.

13 Bulk waste is a waste type that can contain all waste categories (e.g. garden waste, furniture, wood). The detailed composition of the different waste fractions for bulk waste is not known. IPCC default values are based on different studies.

3.1.3.5 Landfill gas used

Overview

Generated CH_4 in landfills can be recovered and used for power generation or it can be flared, if recovery systems that capture CH_4 are installed at the landfills. The amount of CH_4 that is recovered has to be subtracted from the total CH_4 emissions that are generated.

Methodological issues

According to the 2006 IPCC Guidelines CH_4 recovery should only be reported if good documentation on the amount of CH_4 recovered is available. In all other cases, the default value of zero has to be applied for CH_4 recovery. The emissions that arise from the use of the recovered gas for energy use have to be reported in the energy sector.

Good Practice country examples

Landfill gas recovery is still very uncommon in most NAI countries. Within the framework of the CDM, some projects that capture biogas from landfills have been established. Armenia, Brazil and Tunisia are using information available in CDM reports to estimate the amount of CH_4 recovery. Despite this not all countries have available data on CH_4 recovery.

3.1.4 Choice of emission factors and parameters for estimating CH_4 emissions from solid waste disposal

Overview

Besides the activity data, different parameters are part of the calculation of CH_4 emissions from solid waste disposal according to the FOD methodology. Parameters that need to be available include the degradable organic content in the different waste types expressed in Gg C per Gg waste, the half-life value that reflects the years which the degradable organic carbon needs to decompose, the methane correction factor given as a percentage, which reflects the waste management at the disposal sites and other parameters. These parameters are mainly based on chemical analysis and the variation is rather low or only related to different climatic conditions.

In the IPCC waste model all default parameters and emission factors are already included and can be used for each country. A short introduction on the single parameters and factors are included below. Further information is provided in the IPCC Guidelines.

Methodological issues

According to the three Tier methods described in the IPCC 2006 Guidelines the default parameters provided in the model and the Guidelines can be applied in the

Table 3-8: Information on landfill gas recovery in selected countries

Country	Description
Armenia	In December 2009 an Armenian-Japanese joint project was launched in Nubarashen SWDS, within the framework of the CDM, for methane capture from landfill as well as burning and incineration. According to the Project Monitoring Report (2010), 85 tons of CH_4 gas were captured monthly under this project which is equivalent to a about 1.02 Gg CH_4 annually (Armenia, 2014, p. 109).
Bulgaria	The country reports methane recovery from 2010 onwards. The calculation of CH_4 from landfills is based on questionnaires sent to the landfill operators, which contain data about methane stored in reservoirs, flareed and utilized for energy use. The amount of gas collected and utilized as measured at SWDS is reported to the Regional Inspectorate of Environment and Water. Reporting is based on the metering of gas recovered for energy utilization and flaring (Bulgaria, 2014, p. 403).
Brazil	To estimate CH_4 emissions the amount of methane recovered should be discounted. The CH_4 recovery amounts are discounted from the emissions of cities in which CDM project activities take place. Since a landfill can receive waste from several municipalities the amount of methane recovered can be greater than the emissions of a given municipality, which is estimated as a result of its urban population and the other parameters described. For the 1990-2002 period, these amounts were deemed to be zero, since no CDM projects with CH_4 recovery existed. From 2003 onwards, CH_4 emissions reduction reported in CDM monitoring reports for Brazilian landfill projects were considered, for which Certified Emission Reductions were issued by the CDM Executive Board (Brazil, 2010, p. 242).
Chile	For estimating CH_4 recovery, information was obtained from each of the 12 disposal sites in Chile that carry out methane recovery. The assumptions made for estimations were always validated by the experts responsible for compiling waste disposal data on the national level (2014b, p. 142). Most of these methane recovery projects participate in the CDM.
Tunisia	Amounts of CH_4 began to be captured and flared from 2008. The data on the amounts of CH_4 is particularly well documented to the extent that it is part of CDM projects (2014).

Source: Compilation by Öko-Institut

Tier 1 and the Tier 2 method. Only for estimating CH_4 emissions from solid waste disposal based on a Tier 3 method nationally developed key parameters or measurement derived country specific parameters have to be used.

On the basis of the activity data the amount of each single waste fraction including food waste, garden, paper, wood and straw, textiles, disposable nappies and sewage sludge that is deposited in landfills could be calculated in Gg. To calculate the CH_4 emissions from the total amount of food waste and the other waste fractions deposited in landfills their amounts need to be multiplied with several parameters or emission factors. Relevant parameters that are needed for the calculation include:

- **Degradable organic carbon content (DOC)**: Not all of the carbon contained in the waste fraction will decompose. The relevant waste fractions (food waste, garden, paper, wood and straw, textiles, disposable nappies and sewage sludge) have different DOC contents that are accessible to biochemical decomposition (Default: 2006 IPCC, Vol. 5, Table 2.4, p. 2.14). The DOCs have to be measured on a wet weight basis. Thus as food waste contains a high proportion of water the DOC for food waste is lower than for wood waste or other waste fractions with a lower water content.
- **Fraction of DOC which decomposes (DOC_f)**: The DOCf represents an estimate of the carbon content that is actually degraded and emitted into the atmosphere. It is assumed that about 50% of the DOC is actually degraded.
- **Methane correction factor (MCF)**: The methane correction factor accounts for the fact that unmanaged/uncontrolled landfills emit less methane per volume of waste than managed landfills. The factor reflects the type of landfill management (IPCC, 2006).
- **Methane generation rate constant (k) or half-life time**: The decomposition of the organic carbon in the waste takes several years. The Methane generation rate constant presents the time taken for the degradable organic matter (DOCm) in waste to decay to half its initial mass (IPCC, 2006). The half-life is affected by a wide variety of factors related to the waste composition, climatic conditions of the place at which the solid waste disposal site (SWDS) is located, characteristics of the SWDS, waste disposal practices and others. For countries with limited data availability on waste composition, the IPCC guidelines 2006 suggest two approaches:
  - » Bulk waste option: The bulk waste option is suitable for countries without data or with limited data on waste composition, but with good information on bulk waste disposed at SWDS. Default values are estimated as a function of the climate zone.
  - » Waste composition option: The waste composition option is applicable for countries which have data on waste composition. Specification of the half-life (t1/2) of each component of the waste stream (IPCC, 2000) is required to achieve acceptably accurate results. If no national data is available on bulk waste, it is good practice to use the waste composition option in the spreadsheets, using the provided IPCC default data for waste composition.

  For both options default half-life values are estimated as a function of the climate zone.
- **Oxidation factor (OX)**: The oxidation factor reflects the amount of methane from landfills which is oxidized in the soil or in another material covering the waste material (IPCC, 2006). The oxidation factor increases with higher temperature and is highly dependent on the type and thickness of the material that covers the landfill. The OX is highly variable depending on the conditions in the individual landfill. Generalization of field or laboratory research results is not recommended and can lead to an overestimation of emissions. If the landfill is completely covered and no leakage occurs than there is no oxidation at all and the factor is zero. A factor of 1 needs to be applied if there is no coverage and complete oxidation. The use of the oxidation value of 0.1 is justified for covered, well-managed SWDS.
- **Fraction of CH_4 in generated landfill gas (F)**: Landfill gas consists mainly of CH_4 and CO_2. It is necessary to determine the proportion of methane in landfill gas. The methane concentration in gas generated in SWDS is typically around 50%.
- **Methane recovery**: The share of methane that does not escape, but is captured and used for energy or flared (landfill gas). The default value is 0 according to the IPCC, as the recovered methane varies from country to country and can only be determined nationally.
- **Delay time:** Waste can be disposed in landfills on a daily basis. The production of CH_4 does not begin immediately after disposal. Time estimates for the delay are uncertain and will probably vary with waste composition and climatic conditions. The IPCC default value is 6 months.

Good Practice country examples

Within the literature review, all selected countries except Mexico applied default parameters to calculate the emissions arising from solid waste disposal. No further information on the establishment and the use of country-specific parameters are provided.

3.1.5 Recommendations for estimating CH_4 emissions from solid waste disposal

3.1.5.1 Overview

To estimate CH_4 emissions from solid waste disposal it is recommended that the 2006 IPCC Guidelines are applied, as updated and more detailed default data is available. For the calculation, the use of the IPCC Excel model (see Section 5.2) is highly recommended. As this calculation is based on the FOD method, this presupposes the availability of activity data for 50 years. The following recommendations introduce step-by-step the procedure to collect and establish activity data for a time series of 50 years. The recommendations mainly include the adjustment of default or country-specific activity data along the time series. The application of constant activity data from 1950 onwards would overestimate emissions from solid waste disposal. Especially in NAI countries there is an increase of total waste generated due to increased living standards and urbanization trends. Applying recent activity data or default values in the year 1950 would not take this into account. Thus, the focus of the recommendations is based on the adjustment of activity data along the time series according to country specific circumstances.

Activity data needed to estimate CH_4 emissions from solid waste disposal include: population data, waste generation rate, share of total waste landfilled according to different types of waste disposal sites and waste composition. Besides the activity data, further parameters are needed in the calculation. These parameters are available as IPCC default data.

Solid waste that is disposed of in landfills includes MSW, industrial waste, sludge and other waste. As MSW disposed of in landfills has the highest share and only a few countries have activity data on other solid waste types available, the recommendations focus on MSW. If data is available on the other waste types, the recommendations also apply for industrial waste, sludge and other waste. Only waste generation rates are calculated differently (see Table 3-3, Table 3-4).

3.1.5.2 Calculation of total waste generation

To calculate the amount of total waste generated in a country, the total population has to be multiplied with a country-specific waste generation rate.

Population data is available from the UN for all countries from 1950 onwards. If no national statistics are available or if national statistics lack a consistent time series, UN data can be used. Emission estimates depending

Climate zone

Data sources	Country-specific population data according to different climate zones.
Methodology / Recommendation	If there are different climate zones in the country, calculate estimates for each climate zone separately by including the share of population living in the climate zone and selecting the right region in the IPCC model. Data on the share of waste landfilled, type of landfill site and waste composition can be applied to all climatic zones, if there is no detailed data available.
Exemption	If population cannot be distributed to different climate zones, choose the zone in which most of the population lives.
Country examples	Chile (Table 3-1), in many countries not relevant.

Share of rural – urban population

Data sources	If no national statistics are available, use UN data (see Annex II).
Methodology / Recommendation	Calculate the share of urban and rural population, and allocate different waste generation rates, waste landfilled shares and waste treatment data. Prepare two waste models: one for the urban and one for the rural population. Insert urban population, urban waste generation rates, waste landfilled shares, disposal according to the type of treatment sites and waste composition data for urban areas. Insert rural population, waste generation rates in urban areas etc. into a separate model. Add together the CH_4 emissions estimated from urban and rural waste models to determine the total CH_4 emissions from solid waste disposal of the country.
Exemption	If it is not possible to estimate urban and rural population separately due to lack of different waste generation rates etc. and no other assumptions can be made, estimate CH_4 emissions for total population in one model.
Country examples	Namibia, Tunisia (Table 3-1) and Vietnam (Table 3-2).

<table>
<tr><td>Data sources</td><td>National statistics, national studies, data from CDM projects, measurements, IPCC default data.</td></tr>
<tr><td>Methodology / Recommendation</td><td>Example of the calculation of historic waste generation rate:
1. Use country-specific data if available for the most recent year; if no national data is available, apply IPCC default data
2. Download a time series for GDP development in changes in percent (national data or UN data) for the last 50 years,
a. Instead of GDP development annual changes in percent of urban population growth can also be applied or a constant percentage change between 1% and 5% can be used.
3. Subtract the changes in percent from the GDP development from the waste generation rate applied in 2010 for each single year in the time series according to the calculation shown in the table below.
4. Historic waste generation rates in 1960 should not be below 0.2 or 0.1 kg/cap/day (this is equivalent to 36 – 73 kg/cap/year).
5. For the rural population, it is recommended that a lower waste generation rate is applied (see Tunisia or Vietnam Table 3-2).
Example calculation:
<table>
<tr><td>Year</td><td>2010</td><td>2009</td><td>2008</td><td>…</td><td>1961</td><td>1960</td></tr>
<tr><td>Waste generation rate [Unit]</td><td>550</td><td>536</td><td>511.6</td><td>…</td><td>85.7</td><td>82.2</td></tr>
<tr><td>Annual Change GDP %</td><td></td><td>+2.5%</td><td>+4.6%</td><td>…</td><td>0.0%</td><td>+4.0%</td></tr>
<tr><td>Calculation</td><td></td><td>=550-(550*2.5%)</td><td>=536-(536*4.6%)</td><td>…</td><td>=85.7-(85.7*0%)</td><td>=85.7-(85.7*4%)</td></tr>
</table></td></tr>
<tr><td>Country examples</td><td>India, Tunisia, Brazil, Namibia, Vietnam (Table 3-2).</td></tr>
</table>

on population data are sensitive to the share of population living in different climate zones in the country and to the share of population living in urban and rural areas. Therefore, it is recommended that the CH_4 emissions from solid waste disposal are calculated by using separate population data for urban and rural population and separate population data for different climate zones.

Waste generation rate per capita

Waste generation increases with higher income level and growing urbanization. According to IPCC defaults, waste generation rates range from 210 kg/cap/year in Central Asia and Central America and 290 kg/cap/year for Africa to 640 kg/cap/year in Northern Europe.

Waste generation rates that are based on a research study or on IPCC defaults are generally only available for one or a few years in the time series. If they are based on statistics there might be data available for the most recent years, but there is almost no data source available that includes waste generation rates from 1950 onwards.

According to the IPCC Guidelines, defaults are applicable for the year 2000. As waste generation follows consumption and production tendencies, it is more likely that waste generation per capita in 1950 is lower than in the year 2000 and higher in the year 2010. To estimate CH_4 emissions from solid waste disposal, it is recommended that the waste generation rate is adapted along the time series.

Total waste generation to be used as activity data for the other subcategories

Based on the population and on the waste generation rate per capita, the total amount of waste generated in the country is available and can be used for further calculations. The total amount of generated waste is the basic activity data for solid waste landfilled, biological treatment (e.g. composting), incineration and open burning. Based on country-specific circumstances the shares of the different activities vary. To avoid double counting, the sum of all activity data used for the different management practices must be similar to the total amount of waste generated. The following box provides an example of the calculation on the amount of total waste generated that is used in the different subsectors of solid waste.

Box 3: Example calculation of activity data for waste landfilled, composted, open burned, incinerated and other

Total amount of waste generated:

71 million inhabitants x 250 kg/cap/year = 17,719 Gg MSW

Amount of waste landfilled:	55%	x 17,719 = 9,745 Gg
Amount of waste composted:	10%	x 17,719 = 1,772 Gg
Amount of waste open burned:	20%	x 17,719 = 3,544 Gg
Amount of waste incinerated:	5%	x 17,719 = 886 Gg
Amount of waste recycled or unknown:	10%	x 17 719 = 1 772 Gg

Total amount of waste landfilled, composted, open burned, incinerated and recycled:

9,745 + 1,772 + 3,544 + 886 + 1,772 = **17,719 Gg MSW**

3.1.5.3 Share of solid waste landfilled

The amount of waste landfilled varies widely and is strongly related to the amount of waste collected. Collection rates in low income countries are generally lower than in high income countries ranging from 41% in low income countries up to 98% in high income countries (World Bank, 2012b).

Data sources	Statistical data, data from CDM projects, expert judgments, IPCC defaults.
Methodology / Recommendation	If statistical data on the share of waste landfilled is available, this data is used for the most recent years. The share of waste landfilled must have been lower in historic years and might be lower in rural areas. It is recommended that the recent share of waste landfilled is downscaled in a similar way to the adaptation of the waste generation rate by x% per year, if no data is available for the time series.
Exemption	Of total waste generated some parts may be recycled, open burned etc., thus only a share is landfilled. Some countries may not know the exact share of the waste landfilled from total waste generation, but have data available that measures all incoming trucks at the landfills and can estimate the total amount of waste landfilled in gigagram by counting the trucks. Instead of the total waste generation and the share landfilled the measured amount of waste landfilled can be included under "total waste generation" in the waste model and the share set to 100%. The share of waste landfilled can increase due to improved collection systems. The share of waste landfilled can decrease if more recycling takes place or waste policies ban special waste types from disposal on landfills.
Country examples	Vietnam (Table 3-5).

3.1.5.4 Categories of waste disposal sites (managed, unmanaged landfills)

Countries need to estimate the share of waste that is disposed of in different landfill site categories. As this task is very region- and country-specific, there are no IPCC default values provided. The IPCC model includes some dummy data, this means data that is not very useful or realistic to apply for most countries.

Data sources	Statistical data, data from CDM projects, measurements, research studies or expert judgement.
Methodology / Recommendation	Consider the relation of managed or unmanaged deep landfills in large cities and shallow unmanaged landfills in small cities and rural areas. The MCF of managed or unmanaged deep landfills would have to be applied to waste generation rate times population of large cities, etc. If no country-specific data is available for the most recent years (from 2000 onwards), the data included in the IPCC model can be used. For historic years and rural areas the category of "unmanaged shallow" might be appropriate. Otherwise it has to be assumed that 100% of waste is disposed in "uncategorized" landfills.
Calculation example	Total population: 10 mn; population living in large cities: 6 mn (60% of total population); population living in small cities: 1 mn (10% of total population); population living in rural areas: 3 mn (30% of total population). Share of waste going to Anaerobic managed waste disposal sites = 60% Share of waste going to Unmanaged deep waste disposal sites = 10% Share of waste disposed on Unmanaged shallow waste disposal sites = 30%
Attention!	IPCC defaults included in the model for distribution of waste to the different landfill categories are not appropriate for most NAI countries. The data already included in the model assumes that 25% of the waste in 1950 is disposed of in managed landfills, which is not realistic. Please follow the recommendation provided above.
Country examples	Armenia, Kazakhstan, Namibia, Mexico (see Table 3-6).

3.1.5.5 Waste composition

The share of food waste, paper, wood, textiles, nappies and plastics is influenced inter alia by economic development, culture and climate. It varies between regions and throughout the year. Low income countries have the highest share of organic waste (above 60%), while in high income countries the share of food waste is below 30% and the share of paper, plastics and other inorganic materials increase (World Bank, 2012b).

Data sources	Statistical data or research study, data from CDM projects, IPCC defaults.
Methodology / Recommendation	Apply country-specific data (if available) or IPCC default data. Generalize research study results for the total amount of waste disposed and keep it constant along the whole time series if no better data is provided. If there is good data on bulk waste available, choose the bulk waste[14] option in the IPCC model; otherwise, use the default composition data as included in the IPCC model.
Country examples	Armenia, India (Table 3-7).

3.1.5.6 Time series

For solid waste disposal including MSW, as well as industrial solid waste, sewage sludge and other waste, a long time series of about 50 years needs to be established if the FOD method is applied. There are different methodologies for how to set up a time series for such a long period and what data sources can be applied.

Step 1	If possible, divide the long time series of 1960-2010 into different periods according to differences in economic growth, waste management, waste policies or data availability.
Step 2	Apply different assumptions based on data from studies, surveys or expert judgements on waste generation, waste landfilled, waste treatment in the different periods, e.g. the period before the opening of managed landfills and the period after the opening of managed landfills when most parts of the landfilled waste is disposed of in managed landfills.
Option for Step 2	If recent data on waste generation and waste landfilled is available it can be scaled for historic years based on the development of economic indicators or other drivers (see Section 3.1.5.2).
Calculation example	Waste generation rate in 2010 = 459 kg/cap/yr Downscaling factor per year: 0.5% (e.g. based on annual GDP growth or changes of the urban population). Waste generation rate in 2009: 459 * 99.5% = 457 Waste generation rate in 2008: 457 * 99.5% = 454
Option for Step 2	Mix default data with country-specific data, if data is not available along the time series. Mexico divided the long time series into two periods 1950 to 1990 and 1990 to 2010. For the first period no data is available, thus IPCC default data has been applied. In the second period from 1990 onwards, country-specific data could be applied.
Option for Step 2	Apply (weighted) average values if studies for different regions are available or use study results for different years (see Table 3-2 Brazil).
Step 3	Use research studies, survey, expert judgements or statistical methods like interpolation or regression formulas to fill in missing years in the time series.
Attention!	Check that default data or country-specific data in historic years is lower than in recent years (waste generation, share landfilled etc.). Most default data applied for historic years needs to be downscaled as described under Section 3.1.5.2 as it is more applicable to recent years than to historic years. For some countries, default data might be very low in comparison to the recent activity data and can be applied to historic years. Nevertheless, if default data is applied it needs to be checked that historic data on waste generation rate etc. is lower in historic years.
Example	In the example there is country specific data for waste generation from 2000 onwards available. For the year 1990 default data has been applied. This default data is higher for the years 1960 to 1990 than in the year 2000, which is not realistic. (see table below) In this case it would be better to downscale the country specific data available for the year 2000 (see above) instead of using IPCC default data.
Documentation	Document all assumptions, research studies and methods applied.

		1960	1970	1980	1990	2000	2010
		IPCC default				country specific	
Waste generation rate	kg/cap/yr	415	415	415	415	395	445

14 Bulk waste is a waste type that can contain all waste categories (e.g. garden waste, furniture, wood). The detailed composition of the different waste fractions for bulk waste is not known. IPCC default values are based on different studies.

3.1.5.7 IPCC defaults for parameters

In most countries there are no country-specific parameters available and as long as no Tier 3 method is applied it is not necessary to develop country-specific parameters. Default parameters are already included in the IPCC Waste Model (see Section 5.2). In the absence of national models and parameters, it is recommended that the IPCC model is applied with default parameters as described in Chapter 3.1.4.

Some countries have country-specific DOC values for different waste types. If these DOC values are used ensure that they are measured on a wet weight basis and not on a dry weight basis. The water content of food waste is very high in comparison to wood or paper, thus the DOC of food waste is correspondingly lower.

3.2 Biological treatment of solid waste

3.2.1 Overview

The biological treatment of solid waste covers composting and anaerobic digestion of organic waste. Decomposition of biomass during biological treatment is much faster than on landfills and the CH_4 and N_2O emissions are estimated on an annual basis without the need for long time series as in the case of landfills.

The 2006 IPCC Guidelines introduced a methodology for the estimation of GHG emissions from composting, anaerobic digestion and mechanical-biological treatment. The difference between composting and anaerobic digestion is that the former is mainly an aerobic process with anaerobic pockets whereas in the latter the decomposition takes places without oxygen under controlled environmental parameters. Mechanical-biological treatment can include composting, anaerobic digestion, burning and recycling and needs to be analysed individually for each installation.

Methane and nitrous oxide emissions are estimated using the quantity of organic waste processed by treatment type (composting and anaerobic digestion) and the respective emission factors. Emissions from mechanical-biological treatment need to be calculated for each step according to the respective methodologies. Any methane recovered for flaring and/or energy use needs to be deducted from the calculated emissions.

3.2.2 Methodological issues

Choice of activity data

Activity data can come from the same sources as discussed in the sections on solid waste disposal. It is good practice to use national data if available. If no country-specific data is available, the IPCC Guidelines provide some regional default factors (IPCC, 2006) and values used by individual countries (IPCC, 2006) for the fraction of Municipal Solid Waste (MSW) composted. The available information is rather incomplete: neither dataset has values for Africa, the Caribbean, Central America or Oceania. Anaerobic treatment is assumed to be non-existent if a country has no national data.

Choice of emission factor

The IPCC Guidelines provide default emission factors for Tier 1. For anaerobic digestions, N_2O emissions are considered negligible. Tier 2 requires countries to develop a national emission factor; for Tier 3, emissions need to be calculated for each treatment plant separately using individual emission factors.

Completeness and consistency

To avoid double-counting or gaps in the inventory, the following approach should be taken:

- Emissions from the energy use of recovered methane should be reported as a memo item under the Energy Sector.
- Flaring should be reported under Biological Treatment. It is good practice not to estimate these emissions; any CO_2 is of biogenic origin and not accounted for, and N_2O and CH_4 emissions from flaring are considered negligible.
- If sludge from wastewater treatment is disposed of along with solid biological waste, emissions should be reported in this category and not under wastewater.

The 1996 IPCC Guidelines and 2000 Good Practice Guidance did not include this source category. It might therefore be challenging for countries to establish a complete time series if data is not available for all years.

3.2.3 Good Practice country examples

Very few NAI countries have reported emissions from composting so far; the source category was not included in the 1996 IPCC Guidelines. All countries studied use the Tier 1 methodology with default emission factors;

the uncertainty of the emission factor is considered high. The activity data is collected bottom-up using site-specific data in all cases. In some cases the authorities are aware that the reported information is incomplete which will lead to an under-estimation of emissions from composting. In the absence of better data, such an approach is recommended compared to the situation of not estimating emissions from the sector at all.

Anaerobic digestion is not practiced in any of the selected countries.

Table 3-9: Information on biological treatment in various countries

Country	Description
Bulgaria	Emissions from composting are estimated using Tier 1 emissions factors and with national statistics for the activity data. Activity data is only available from 2011 onwards and prior emissions are not estimated. The uncertainty of the default emission factor is assumed to be 100%; the activity data has an uncertainty of 10% (Bulgaria, 2014, p. 431).
Chile	A Tier 1 methodology that involved the use of default emission factors provided in the 2006 IPCC Guidelines was used. As there is no registry of Chilean facilities that perform biological treatment of solid waste, the team recurred to projects of this kind evaluated by the Environmental Impact Assessment System. The team also visited and contacted some companies and large municipalities that had composting programs in place in order to generate useful figures (Chile, 2014b, p. 149).
Germany	Since 1995, the Federal Statistical Office has regularly collected and published data on waste quantities managed in MBT systems. There was doubt as to whether the data of the Federal Statistical Office covers all types of facilities that, in terms of their emissions behaviour, must be grouped with MBT facilities. As a conservative approach therefore, emissions calculation was carried out using the higher waste quantities determined by a research project. Via a number of discussions with the Federal Statistical Office those doubts have since been eliminated (Germany, 2014, p. 649).
Mexico	There are no official statistics or regulations that cover composting; anaerobic digestion does not occur in Mexico. Activity data is held constant for the entire time series. It is based on a study from 1990 which has information about composting in five of the largest cities. These values are uncertain because most of the existing composting facilities have not been working for the entire time series. Default emission factors are used. The uncertainty of the default emission factor is assumed to be 50%; the activity data has an uncertainty of 100% (Mexico, 2012, p. X-162).
Tunisia	Emissions for composting are estimated using default emission factors and national statistics. Operators are obliged to report the quantities of organic waste composted but it is unclear whether all operators report and are included in the statistics. The uncertainty is therefore assumed to be 20 %, doubling the normal uncertainty for Tunisian statistics; 100% uncertainty is assumed for the emission factor based on the range given by the IPCC (Tunisia, 2014).

Source: Compilation by Öko-Institut

3.2.4 Recommendations

Data on composting is incomplete in most countries. While the practice exists in many countries, it is often conducted at a local level with no data collection and/or reporting requirements. If possible, use existing data and apply the general gap-filling methodologies (e.g. Chile, Table 3-9). If a complete time series cannot be established, only calculate emissions for recent years. For earlier years, use notation key NO (Not Occurring) if the practice did not exist or NE (Not Estimated) if the practice existed but no emission estimate was possible. Ensure consistency with activity data in the other waste categories (i.e. in the case of biological treatment of sludge).

3.3 Incineration and open burning

3.3.1 Overview

Waste can be burned in installations, burned openly or self-ignite on unmanaged landfills. Open burning typically takes place on the ground, in barrels or in open dumps and is a common practice in many non-Annex I countries. In addition to the greenhouse gases covered by the reporting guidelines, open burning is also a source for black carbon and other pollutants with resulting impacts for the air quality. Black carbon is also a driver for climate change but it is not required to be reported under the IPCC Guidelines. Waste incineration is more common for hazardous and/or medical waste whereas incineration in controlled facilities rarely takes place in NAI countries. The 1996 IPCC Guidelines and 2000 Good Practice Guidance only include a methodology for incineration; open burning was introduced in the 2006 IPCC Guidelines. The methodology for estimating emissions is the same for both types of combustion; they differ in the emission factors and oxidation rates.

CO_2, CH_4 and N_2O are generated during the combustion process. For CO_2 only emissions from fossil sources (e.g. plastics or some textiles) are included in the net national totals; emissions from biomass materials (e.g. paper or food) are not included. If the heat generated is used for energy purposes, emissions have to be reported under the energy chapter. Typically this takes place in electricity generation or co-combustion for process heat, for example in cement installations.

3.3.2 Methodological issues

Choice of method for CO_2 emissions

The methodology requires the calculation of fossil carbon burnt per waste type. To do so, it is necessary to estimate the fossil fraction per waste type. The Guidelines provide methodologies and default values to convert the wet or dry weight of the waste into fossil carbon. It is good practice to differentiate between different waste types if the information is available. For Tier 1, countries can use the default factors provided in the IPCC Guidelines; for Tier 2 and Tier 3 it is necessary to develop country-specific or installation specific data.

Choice of method for CH_4 and N_2O emissions

To calculate emissions of methane and nitrous oxide, it is necessary to estimate the quantities of waste burned by type and combustion technology. For Tier 1 default emission factors and approaches for estimating activity data are provided; for higher tiers it is necessary to develop national or site-specific information.

The activity data used per waste type should be identical for the calculation of all three greenhouse gases.

Activity data

Incineration of MSW typically takes place in a relatively low number of controlled installations if at all. It is good practice to collect data from these installations if possible. If not, some default and country-specific values are provided (IPCC, 2006) but information for NAI countries is very limited. It is good practice to analyse the composition of MSW incinerated as it might differ from the composition of MSW generated. If country-specific data is generated, it is important to ensure representativeness of the samples. Hazardous and clinical waste is often burned on site in hospitals and industry and the collection of plant-specific data might not be possible.

Open burning of waste is a common practice and should be considered in detail. Burning can be intentional or due to self-ignition on unmanaged landfills. In the absence of official data, the guidelines provide a methodology to estimate the amount of waste burned openly. The following is required:

1. Population burning waste: This is the population for whom waste is not collected or waste is sent to open dumps where burning takes place; typically this includes the rural population and some part of the urban population, depending on national circumstances.
2. Per capita waste generation rate for population burning waste: This might be different from the national average because open burning typically takes place in low-income areas but in the absence of detailed data it is good practice to be consistent with the generation rates used for solid waste disposal and biological treatment.
3. Fraction of waste burned: Open burning of waste is an incomplete process. The default assumption is that 60% of the waste is actually oxidised; 40% remains together with the ashes on site.

Emission factors

For CO_2 anthropogenic emissions depend on the fossil carbon content of the waste. The same parameters as used for solid waste disposal should be used to estimate fossil carbon. For open burning not all carbon is actually converted to CO_2; an oxidation factor of 58% is given as the default. Emissions of CH_4 and N_2O depend on the combustion technology. The 2006 Guidelines provide default values for different types of incineration installations and for open burning. If no country-specific information is available, it is good practice to use the default values.

Completeness and consistency

It is necessary to carefully reflect incineration and the open burning of waste in various source categories to avoid double counting or omissions:

- Energy: If the heat generated through incineration is used for electricity generation or for other energy use such as co-combustion in industry, related emissions should be reported under energy,
- AFOLU: Agricultural residue burning should be reported in the AFOLU sector,
- Solid waste disposal: The amount of waste burned might need to be deducted from the amount of waste which is transported to solid waste disposal sites depending on national circumstances. If open burning takes places in landfills, it reduces the available degradable organic carbon (DOC); this should be estimated and reflected in the calculations for emissions from solid waste disposal.

It is good practice to ensure the consistency of data across all these source categories.

3.3.3 Good Practice country examples

Waste incineration in controlled installations is not yet practiced in most developing countries except for hazardous and/or medical waste. In the absence of official statistics, several countries use the quantity of hospital beds and waste generation rates per bed to estimate the necessary activity data.

Most developing countries use the population in rural areas as the basis for determining emissions from open burning of waste. The fraction of waste burned by the rural population varies according to national circumstances and information available from 20% (Tunisia) to 100% (Armenia) in the analysed countries. It is good practice to explain these values and document the assumptions made. Some countries have national data on MSW composition; for all other parameters default values from the IPCC Guidelines are used. Tunisia explicitly reported a mechanism to achieve consistency between waste and energy emission inventories concerning activity data and waste composition. It is good practice to ensure such consistency.

Table 3-10: Incineration and open burning of waste in various countries

Country	Description
Armenia	100% of the waste generated by the rural population is burned openly. (Armenia, 2014, p. 112).
Ghana	To improve data availability the responsible ministries will collect data on incineration of food and biomedical waste through local governments. The Environmental Protection Agency (EPA) will analyse the reports and provide feedback directly to the data providers in order to improve data quality. For open burning, districts need to estimate the quantities and report to the Ghanaian local government ministry. Academia is involved in the data collection process in order to improve data quality. (Ghana 2015).
Mexico	Waste incineration only takes place in the case of hospital waste. Facilities are regulated by the environment ministry and there are official statistics for the quantity of waste incinerated. Open burning of waste takes place in the rural areas. It is estimated that 40% of the waste generated by the rural population is burned. 2006 IPCC Guidelines default factors are used for the estimation of GHG emissions (Mexico, 2012, p. X-11).
Tunisia	The estimation of quantities of medical waste incinerated in 2010 is based on several parameters: capacity (number of beds) of institutions incinerating medical waste, medical waste per bed and the bed occupancy rate for the year in question. Tunisia estimated the quantity of household waste disposed through open burning in the country based on expert judgements (20% of the waste generated by the rural population). National data on waste compositions and quantity together with IPCC default factors for all other parameters were used to estimate CO_2, CH_4 and N_2O emissions. An exchange takes place between the experts responsible for the energy sector and waste sector to ensure that all waste is accounted for and the same waste composition is used for municipal solid waste (2014).
Vietnam	From 2006 to 2010, the amount of hazardous medical solid waste burned in incinerators was collected from 5 years of environmental status reports. For 2000-2005 the number of hospital beds and waste generation rates (0.86 kg waste/bed/day and 0.14 kg hazardous waste/bed/day) were used. Incineration of MSW started around the year 2000 in some cities. Activity data is collected for each installation (Vietnam, 2014, p. 239).

Source: Compilation by Öko-Institut

3.3.4 Recommendations

For the incineration of hazardous medical waste try to identify the incineration plants and collect activity data. If not possible use the number of hospital beds as a proxy for generation rates is available (e.g. Tunisia, Table 3-10). If waste incineration for MSW takes place, collect activity data directly.

Using national estimates, estimate emissions from open burning based on:

- the population not connected to formal waste collection systems and
- the quantity of waste going to open pits where waste is burned.

If possible, use national estimates for the share of waste burned (e.g. Table 3-10 Mexico).

Ensure consistency with the activity data in the other waste categories and reporting under energy.

3.4 Wastewater treatment and discharge

3.4.1 Overview

Emissions from treatment and disposal of wastewater need to be reported here. Methane emissions occur under anaerobic conditions, i.e. in deep and slowly moving waters. They can originate during all stages from wastewater generation to final disposal. The emissions depend on the carbon content of the wastewater, the treatment or disposal method and temperature. To calculate the emissions, wastewater generation needs to be estimated for domestic wastewater (i.e. mainly human sewage) and some industrial activities. For each type of wastewater, it is also necessary to estimate the share of each treatment or disposal method. In addition, nitrous oxide can also be emitted either directly during processing or indirectly after disposal of effluent.

Emissions from energy use of any methane generated and the emissions originating from disposal of sludge in landfills (see Chapter 3.1), on land (under AFOLU) or in anaerobic digestion (see Chapter 3.2) are not included in this source category.

3.4.2 Domestic wastewater

3.4.2.1 Methodological issues

All wastewater generated by households as well as any wastewater not disposed of on site in industrial installations is reported as domestic wastewater. Emissions from all wastewater collected through public sewers are reported here; typically this includes industries and facilities in urban areas such as butchers, restaurants and grocery stores. To estimate methane emissions it is necessary to:

1. determine the total Organically Degradable Carbon (TOW) in domestic wastewater;
2. determine emission factors for each pathway and system for wastewater treatment existing in the country (e.g. untreated discharge into rivers, aerobic treatment and septic tanks); and
3. determine the relative share of each pathway and system and calculate corresponding emissions.

Total organically degradable carbon is based on the total population and the quantity of carbon discharged per person and day expressed in Biochemical Oxygen Demand (BOD). Default values are provided for some countries and it is good practice to use the value of a nearby comparable country. Default values are also provided to estimate the methane emission factors for each pathway and system. To determine the relative share of each pathway and system, it is good practice to categorize the entire population in three groups with distinctive wastewater treatment patterns:

- rural
- urban low income
- urban high income.

In countries with well-developed wastewater facilities, it is not necessary to differentiate the urban population. It is good practice to draw a diagram of the different treatment types and shares to ensure completeness. Some data on the fraction of the population in each category as well as the fraction of the relevant treatment types is provided in Table 6.5 of the Guidelines (IPCC, 2006) for individual countries. To reflect industrial and commercial wastewater discharged into sewers, the population based activity data is multiplied with a constant factor.

If methane is recovered and burned, the emissions from wastewater need to be adjusted accordingly. If sludge is removed from the wastewater, a corresponding quantity needs to be deducted from the Total Organically Degradable Content (TOW). Emissions from sludge decomposition are reported under solid waste disposal, biological treatment, burning or in the AFOLU sector depending on the disposal method. It is good practice to ensure that any sludge deducted under this source category is reported elsewhere.

3.4.2.2 Good Practice country examples

Most developing countries apply Tier 1 methodologies for wastewater. The main difficulties encountered are related to the types and shares of wastewater treatment/disposal pathways. The 2006 IPCC Guidelines recommend differentiating between three groups of the total population which have their own typical pathways:

- urban high income;
- urban low income; and
- rural.

This approach is used by many countries but adapted to national circumstances. In Armenia the treatment type depends more on settlement size than on income class and the inventory is calculated accordingly. Namibia has plant-specific data for the largest wastewater treatment plant in the capital, which is used directly in the inventory. For the other regions default values and expert judgements are applied. South Africa includes a detailed table with all relevant information in the national inventory report.

Bulgaria reports that methane recovery is calculated based on questionnaires sent to the operators of wastewater treatment installations. As required for good practice, Chile ensures that emissions from sludge removed from wastewater treatment facilities are reported elsewhere.

Table 3-11: Methane emissions from domestic wastewater

Country	Description
Armenia	The 2006 IPCC Guidelines do not recommend any default values for BOD for Armenia, South Caucasian countries or the former USSR republics. For that reason, default values recommended by the Revised 1996 IPCC Guidelines for former USSR republics are used. The population is classified into three groups based on settlement size: large cities, other towns and villages. The respective treatment types are (Armenia, 2014, p. 116): * cities: 95% sewer, 5% latrines; * towns: 50% sewers, 50% latrines; * villages: 5% sewers, 95% latrines.
Bulgaria	The calculation of CH_4 recovery from wastewater treatment is based on questionnaires sent to operators of water supply and service utilities. They include information about the type of treatment system for CH_4 utilization (e.g. gas holder system, methane tanks and gas burning system); quantity of total recovered CH_4, CH_4 stored, utilized and flared methane and year of commissioning of the installation for CH_4 recovery (Bulgaria, 2014, p. 412).
Chile	The sludge removed during wastewater treatment is sent to different destinations. The bulk of it ends up in landfills; CH_4 emissions for these types of solid waste disposal sites are accounted for under the "solid waste disposal" category. Another portion of sludge is disposed of in agricultural operations as compost (Chile, 2014b, p. 145).
Namibia	Good flow and Chemical Oxygen Demand data is available for the major wastewater treatment plant in the country. This data is complemented by expert judgement and default values for other regions. The BUR contains a detailed table with population data, wastewater generation and treatment type for 13 regions in Namibia (Namibia, 2014, pp. 86).
Vietnam	There is no statistical data for the type of wastewater treatment or discharge pathway in each income group. The parameter is decided by expert assessment and the weighted average of the fraction of the type of treatment or discharge pathway (Vietnam, 2014, p. 234): * centralized, aerobic treatment plant: 2% * septic system: 55% * untreated: 43%
South Africa	The NIR includes a detailed table on treatment type or discharge pathway (septic tank, latrine, sewer stagnant, sewer closed, sewer open & warm, sewer flowing, none, other) per income group (rural, urban high-income, urban low-income) (South Africa, 2014, p. 243).

Source: Compilation by Öko-Institut

3.4.2.3 Recommendations

Use appropriate groupings of the population, either along the lines of the IPCC Guidelines (urban high income, urban low income, rural) or using other criteria such as settlement size (e.g. Armenia, Table 3-11). Ensure that all wastewater is included in the calculations; this can be achieved by preparing a water flow diagram as suggested by the IPCC Guidelines (see section 3.4.2.1).

3.4.3 Industrial wastewater

3.4.3.1 Methodological issues

Emissions from industrial wastewater include all wastewater that is treated/disposed of on site and not sent to public sewers. The main sources for methane emissions from industrial wastewater are:

- pulp and paper manufacture;
- food and drink processing (e.g. meat and poultry processing, alcohol/starch production and dairy products); and
- organic chemicals production.

Due to the lack and methodological difficulties of obtaining site-specific data, it is good practice to use top-down approaches. Activity data is based on production output from the relevant industries and a Chemical Oxygen Demand per unit of output for each industry. Default values are provided and it is good practice to use them in the absence of national data. Typically only three to four industry sectors are relevant per country and it is good practice to focus efforts on these industries. It is good practice to re-evaluate all potentially relevant industrial sectors periodically. Once an industry sector is included, it should remain in all subsequent years in the inventory. If new sectors are included, countries should re-calculate the entire time series.

3.4.3.2 Good Practice country examples

The main challenge for countries applying Tier 1 is to determine which industrial sectors are relevant, collect the respective activity data and the type of wastewater treatment. Some countries have detailed data. In Chile, for example, industrial wastewater has been regulated by the government since 2006 and relevant parameters are monitored for control purposes. India conducted extensive literature research and on-site visits to compile the necessary data. In Vietnam country-specific values for Chemical Oxygen Demand have been developed.

3.4.3.3 Recommendations

If possible collect data in three steps: (i) identification of major industries and production quantities; (ii) estimation of wastewater generation from these industries per unit of output; (iii) elaborate country specific Chemical Oxygen Demand for these industries (see Vietnam, Table 3-12)

Table 3-12: Methane emissions from industrial wastewater

Country	Description
Chile	Information for the entire country was available for 2006 to 2010; previous years were estimated using data extrapolated from this period. (2014b), p. 145). Several methodologies were checked for the extrapolation. The best option identified was to use annual GDP changes as a driver for the change in wastewater generation and IPCC default emission factors (Chile, 2015).
India	Data on industrial wastewater is complex due to different processes and products involved in generating different quantity and quality of waste. The data was obtained through extensive literature research and industrial visits. Default values are utilized and marked with reference for unreliable data sets (India, 2012, p. 74).
Vietnam	Activity data is collected in three steps: identification of major industries in the country and production quantities; estimation of wastewater generation from these industries per unit of output; country-specific Chemical Oxygen Demand for these industries. The NIR includes all relevant data (Vietnam, 2014, p. 227).

Source: Compilation by Öko-Institut

3.4.4 Nitrous oxide emissions from wastewater

3.4.4.1 Methodological issues

Direct emissions of N_2O during processing only occur in countries with predominantly advanced centralized wastewater treatment plants with nitrification and denitrification steps. Indirect emissions come from wastewater treatment effluent discharged into aquatic environments. For direct emissions the quantity of wastewater treated in such facilities needs to be multiplied with a default emission factor. For indirect emissions, it is necessary to estimate the nitrogen in wastewater based on protein intake per person and correction factors to reflect non-consumed proteins and industrial/commercial co-discharged into the sewer system. If sludge is removed, a corresponding quantity of nitrogen needs to be deducted.

N_2O emissions from industrial wastewater sources are believed to be insignificant and do not need to be estimated.

3.4.4.2 Good Practice country examples

Calculating nitrous oxide emissions from wastewater is a relatively straightforward process requiring very little data. The IPCC Guidelines only contain a Tier 1 methodology so it is good practice for all countries to use Tier 1 with default emission factors. Population statistics are readily available and the average annual protein intake is provided by the FAO. Some countries reported on their approach to gap-filling FAO data or nationally collected data for protein consumption. No analysed Non-Annex I countries reported direct N_2O emissions from the treatment process itself.

3.4.4.3 Recommendations

Use the same population statistics as for solid waste disposal to ensure internal consistency of the estimates. Apply Tier 1 and use default parameters as included in the 2006 IPCC Guidelines.

Table 3-13: Nitrous oxide emissions from wastewater

Country	Description
Armenia	For protein consumption, the FAO gives averaged figures for the periods of 1990-1992, 1995-1997, 2000-2001, and 2006-2008. The data are interpolated for interim years, while they are extrapolated for years 2009 - 2010 (Armenia, 2014, p. 123).
Vietnam	According to the annual report of the Vietnam's National Institute of Nutrition, per capita protein consumption increased from 22.7 kg/person/yr in 2000 to 26.4 kg/person/yr in 2005 and 27.1 kg/person/yr in 2010 (Vietnam, 2014, p. 237).

Source: Compilation by Öko-Institut

4. NAMAs in the waste sector and their relation to GHG inventories

Many countries have started to implement policies and measures that have an impact on GHG emissions in the waste sector. Many of these policies have been motivated for reasons unrelated to climate change (e.g. health benefits) or list climate change only as a co-benefit. Nationally Appropriate Mitigation Actions (NAMAs) however, are actions by developing countries specifically introduced to reduce emissions while tackling development challenges. According to the UNFCCC, NAMAs refer to any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative. NAMAs can take many forms, from policies directed at transformational change within an economic sector, to actions across sectors for a broader national focus. NAMAs have the commonality that they need to have a Monitoring, Reporting and Verification (MRV) system and contribute to sustainable development in a country.15 The objective of an MRV system is to determine the emission reductions achieved through a NAMA, addressing also some non GHG impacts in line with national development goals. The MRV system can be similar or linked to the GHG inventory but there is not necessarily a need to estimate total emissions. Independently of the purpose of any policies and measures in the sector there are linkages between the inventory and actions taken. This section explores how inventories can influence NAMA and policy development and vice versa. The terms NAMA, policy and measure as well as action are used interchangeably because the considerations below hold true for all of these interventions. Due to a lack of implemented NAMAs in the waste sector no country-specific examples on the estimation of emission reductions and the linkages to the GHG inventory are given.

Using a GHG inventory for policy development

A GHG inventory in the waste sector can be used in several ways during the identification and development of NAMAs and other policies and measures in the sector:

- **Identification of relevant (sub-) sectors**: One of the first steps in developing a policy and/ or NAMA is the identification of reduction potentials. A GHG inventory can give a first indication for the relevance of different (sub-) sectors and emission sources. For example, a NAMA intending to reduce GHG emission from industrial wastewater treatment can use the inventory information to identify the most important industrial sectors. If an action is decided for other purposes such as air quality the ensuing GHG emissions reductions can be used as an additional justification of the action.
- **Identification of key parameters**: After relevant (sub-) sectors have been identified the policy intervention needs to be developed. The parameters used in the inventory development can support this process if their respective relevance for the total GHG emissions is analysed. For example, country specific waste composition data can help focusing recycling and waste separation programs.
- **Estimation of the reduction potential**: The methodologies and data compiled for inventory identification can be used to estimate the reduction potentials and develop different scenarios (ex-ante). For example, the IPCC FOD model for solid waste disposal can easily be used to estimate the impact of an action that intends to introduce composting in a country. By changing the waste composition values it is possible to estimate the impact of different penetrations of the action (e.g. 5%, 10% and 50% collection rate for organic waste).
- **MRV system**: The methodologies, data and parameters used in the inventory can sometimes be directly used in the MRV system of a NAMA or policy. In the example of a large-scale composting program in a country a FOD model can be used to calculate baseline emissions (e.g. with fixed waste composition) and to calculate actual emissions in the project scenario. Such a direct use of inventory methods and data is not always possible; this is especially the case if the impact of the action is small compared to the total GHG emissions from a sector. Using the same example the national inventory would not be a good basis for estimating the impact if waste separation is only introduced in one smaller city in the country. Still, even in such cases the methodologies and data are often useful in the development of the dedicated MRV system.

Waste policies and the GHG inventory

Once a policy has been developed and implemented it can also have impacts on the GHG inventory in the waste sector:

- **Inventory improvement**: If a policy has a dedicated MRV system which is separate from the GHG inventory the data gathered might help improve the quality of the inventory. For example, if the MRV system of an Industrial Wastewater NAMA measures country-specific Chemical Oxygen Demand the results could be

15 For an introduction to NAMAs see GIZ, 2012.

used either as a QA activity of the default values and/ or directly for the inventory if the values are deemed to be representative for the whole country.

- **Reflecting the impacts of the policy**: A national GHG inventory should capture all emissions and removals without over- or underestimating actual emissions (IPCC 2006, Vol. 1, p. 3.8). The GHG inventory should therefore be able to reflect the impacts of any actions taken in the waste sector independently of the monitoring system of the action. To do so it might be necessary to improve the methodology used in the inventory. Coming back to the example of the introduction of a composting policy in a country: if the quantities of organic waste sent to composting are not deducted from the waste going to landfills emissions will be structurally overestimated. To do so it might be necessary to move from IPCC default parameters for waste composition to country specific data.

5. Waste emission models

5.1 Overview

Various models are available in the field of waste management that focus on different perspectives of waste management, GHG emissions and life cycle assessment. Most models use the same input data that are used for calculating CH_4 emissions from solid waste, including waste generation rate, waste composition and waste treatment. Models like the IPCC Model are used to calculate CH_4 emissions from solid waste disposal applying the complex FOD method. The results of the calculations are used in GHG emission inventories and can furthermore indicate the importance of this sub-sector with regard to emission reduction potentials. In a second step other models as the Solid Waste Management Model can be applied to calculate possible mitigation potentials, which is the first step of the NAMA development.

The following chapter introduces some models that can provide further assistance in compiling GHG inventories, activity data and assessment of mitigation potentials in the waste sector. This section gives an introduction to the IPCC waste model and the Solid Waste Management – GHG calculator and provides a short overview on goals and data input for other models available in the waste sector.

5.2 Recommended Models for the estimation of GHG emissions from waste

Depending on the type of emissions, its source and the scope of the inventory, several models to choose from exist. In the following, two main models are presented in more detail; other relevant models are summarized in a table under 5.2.3. The presentation of models is concluded with a motivation for the choice of model.

5.2.1 IPCC Waste Model

Together with the 2006 IPCC Guidelines, a simple Excel spreadsheet model to calculate CH_4 emissions from solid waste disposal has been published. This model is developed on the basis of the calculation according to the 2006 IPCC Guidelines and applies the First order of Decay (FOD) method.

The focus of the model is the estimation of CH_4 emissions from solid waste disposal for inventory compilation.

As default data is already included in the model, each country can easily use this model to calculate emissions from solid waste disposal. If choosing a Tier 1 method countries can use default values, without having country-specific activity data available.

For the Tier 1 method, countries need to select or insert:

- region (the IPCC waste model includes 19 different regions),
- default data based on waste composition or on bulk waste,
- climatic conditions of the country (dry temperate, wet temperate, dry tropical, moist and wet tropical), and
- population in millions, beginning in 1950/1960 (available from national statistics or under the UN database).

Thus by choosing the region, the climatic conditions of the country and entering the population data, the model spreadsheet calculates results for CH_4 emissions from solid waste disposal sites of the country using the FOD method. All countries should be able to calculate their CH_4 emissions from solid waste disposal according to the Tier 1 method by using the IPCC model. If countries want to apply higher tier methods and have more detailed activity data available, they can enter country-specific data into the model.

There is default data available for everything except population. The IPCC default data included in the model is based on studies from the 1990s and the early 2000s. By selecting the region in which the country is located, the default activity data and parameters that are applicable to the special region will be entered automatically to the model.

Default activity data included in the model and in the IPCC Guidelines is not adapted along the time series. Thus IPCC default data for waste generation, waste disposal, disposal on different types of landfill sites and waste composition is constant from 1950 to 2012. Especially for NAI countries this is not appropriate and leads to overestimation of emissions from solid waste disposal. To produce more reliable results, it is recommended that the default data or the country-specific activity data over the time series is adapted as explained in Chapter 3.1.5.

5.2.2 Solid Waste Management - GHG calculator (IFEU)

Whereas the IPCC model is applied to calculate emissions from solid waste disposal the Solid Waste Management Model is used to identify mitigation potentials in the waste sector, which is a prerequisite for NAMA development (see Chapter 4)

The Solid Waste Management (SWM) – GHG calculator has been developed by the Institute for Energy and Environmental Research (IFEU) and shall be used to assess the climate effect of different waste management options. The IPCC Guidelines can be used to calculate emissions from waste, but they do not reflect the actual potential for reducing GHG emissions by the waste management sector. By applying the SWM-GHG calculator, the positive impacts of reducing, re-using or recycling of waste as well as waste-to-energy strategies on climate protection will become evident. Therefore, all waste management practices for solid waste are covered, including landfilling, open burning, incineration, mechanical-biological treatment (MBT), composting and digestion. The focus is on low- and middle income countries that face the considerable challenge of managing increasing waste generation. By including the costs for single waste management options, countries will be able to calculate the costs of different waste management options and calculate how to reduce GHG emissions at comparably low costs and significantly improve health conditions and environmental protections (Ifeu, 2010).

The calculation is based on a life cycle assessment, that includes all steps of waste management (collection, recycling, burning, composting, disposing) and applies the Tier 1 approach of the 1996 IPCC Guidelines. Thus, as there is no FOD method applied, data needs to be available for only one year in time.

Besides the status quo, a probable baseline scenario and two other scenarios can be defined. The new scenarios can assume more advanced waste management such as increased waste collection and recycling or even modern waste management practices like waste to energy strategies.

The results are presented in single sheets for each scenario and include information on activity data as well as on emissions and avoided emissions distributed across the different management options. Information on the total costs of the calculated scenario as well as specific costs for one tonne CO_2eq in the calculated scenario are also provided.

5.2.3 Short presentation of other selected waste models

Besides the IPCC model and the SWM-GHG calculator there are other models available that deal with different aspects of waste management. These models have been assessed to check whether they provide some further assistance (e.g. on activity data or default parameters) for calculating emissions or mitigation potentials from solid waste. A short summary of all models is provided in Table 5-1, which may be helpful in further improving the waste management and the inventories. All links to the relevant models are included in Annex II.

To estimate CH_4 emissions from solid waste disposal, the application of the IPCC waste model is recommended. As calculation is automatized, only activity data needs to be included and emissions are estimated based on the FOD method. Other models do not provide additional or easier guidance to calculate reliable CH_4 emissions from solid waste disposal.

The input activity data used in the IPCC model can be collected by the Urban Solid Waste Management Tool; it is useful to collect consistent activity data from all cities. If no national statistics or other data sources on municipal or regional level are available this tool can be distributed among regional governments and requested to be applied. Nevertheless, this model requires a lot of detailed activity data that exceeds the data input needed for the IPCC model.

To estimate emissions from the other solid waste sub-categories (composting, open burning etc.), the GHG calculator provided by IGES can be used, especially in Asian countries, for which the model has been developed. The Biogas Model and the Waste Management Model focus on the calculation of reduction potentials in the waste sector and it is recommended to apply them for NAMA development if no other sources on the calculation of mitigation potential in the waste sector are available.

Table 5-1: Model Overview

Model	Objective	Sub-sectors covered	Method	Years	Default data	Usefulness
Data collection tool for urban solid waste management (World Bank, 2012a)	Consistent data collection to help decision makers to make waste management plans	Collection, transfer, recycling, landfill, composting, waste to energy	–	One year, historical years can be added for landfills	No	Activity data can be used as input data for IPCC model. Very detailed information is required and will be hard to assess. Not all information is needed as there is data input for the IPCC model.
IPCC model	Calculation of CH_4 emissions from solid waste disposal	Solid waste disposal	FOD	At least 50 years	Yes	Calculation of reliable estimates of CH_4 emissions from solid waste disposal, if activity data is adapted over the time series. Also applicable if no activity data is available.
Solid Waste Management – GHG calculator (Ifeu, 2010)	Estimation of mitigation potentials from solid waste	Recycling, disposal, composting, digestion	Mass balance	One year	Least developed and middle income countries	Very useful for the estimate of mitigation potentials, as different scenarios can be applied.
GHG calculator for solid waste sector (IGES, 2013)	Calculation of emissions along the waste stream, decision-making	Disposal, composting, digestion, MBT, recycling, incineration, open burning, transportation of waste	FOD	Monthly waste generation	IPCC	Very useful for estimating emissions from other sub-categories (Open burning, incineration, composting etc.).
Biogas model (US EPA, 2007)	Calculation of mitigation potential for methane recovery in landfills	Solid waste disposal, single landfill or whole country	FOD	At least 20 years	Detailed for Latin American countries	Useful to estimate mitigation potential from CH_4 recovery, default data for Latin American countries can be used in the IPCC model.
Waste Reduction Model WARM (US EPA, 2015)	Help solid waste planners to track and voluntarily report GHG emissions reductions from several different waste management practices	Source reduction, recycling, combustion, composting, and landfilling	Materials life-cycle approach			Useful to estimate emissions reductions from several different waste management practices WARM is intended as planning tool and not as a GHG accounting tool

6. Outlook and conclusions

As the report has shown, greenhouse gas inventories in the waste sector can serve multiple purposes:

4. Compliance with international requirements under the UNFCCC;
5. Raising awareness about emissions and practices in the sector; and
6. Development of new and improvement of existing policies and measures, mitigation activities, NAMAs and other actions in the sector.

Such co-benefits can help to justify the expense of inventory compilation and vice versa it can be useful to identify co-benefits and utilize them.

The 2006 IPCC Guidelines provide detailed instructions for inventory preparation. First estimates applying Tier 1 and default values can be carried out even when there is very limited national data. Improving the quality and accuracy of the emission estimate can become more complex. Even in the absence of existing data, countries have managed to identify proxy information or develop new data gathering procedures to enable them to move to higher tiers.

One way of reducing the necessary effort and using available resources effectively is to develop a national inventory system which is able to comply with the IPCC good practice requirements. These include conducting key source analysis and selecting appropriate methodologies, estimating uncertainties and the development of a QA/QC plan. Developing and implementing such an inventory system is especially useful if the GHG inventory is to be prepared frequently, e.g. every two years for the Biennial Update Report.

Many Non-Annex I countries are in the process of developing the necessary capacities for inventory preparation. Different UN organisations as well as many national development agencies have funds and programmes which can support capacity development for the monitoring, reporting and verification of greenhouse gas emissions and mitigation measures. Countries in need of support should contact these agencies to investigate possibilities. Some links to programmes and institutions are included in Annex II. The objective of such capacity development measures should always be to enable the country to develop inventories on their own. This has been achieved in several countries included in this study.

7. Bibliography

Armenia, 2014, National Greenhouse Gas Inventory Report of the Republic of Armenia (2010) under the United Nations Framework Convention on Climate Change.

Brazil, 2010, Second National Communication to UNFCCC.

Bulgaria, 2014, National Inventory Report 2014 for Greenhouse Gas Emissions Submission under the UNFCCC and the Kyoto Protocol.

Bulgaria, 2015, 'Questionnaire on waste inventory compilation Bulgaria'.

Chile, 2014a, Executive Summary Chile's first Biennial Update Report to the United Nations Framework Convention on Climate Change.

Chile, 2014b, Chile's National Greenhouse Gas Inventory, 1990-2010.

Chile, 2015, 'Questionnaire on waste inventory compilation Chile'.

China, 2012, Second National Communication on Climate Change of The People's Republic of China.

Germany, 2014, National Inventory report to UNFCCC 1990-2012.

Ghana, 2015, 'Questionnaire on waste inventory compilation Ghana'.

GIZ, 2012, Nationally Appropriate Mitigation Actions (http://mitigationpartnership.net/sites/default/files/giz_nama_ta_source_book_1.0.pdf_0.pdf) accessed 14 July 2015.

Ifeu, 2010, SWM GHG Calculator – a Tool for Calculating Greenhouse Gases in Solid Waste Management (SWM), Eschborn (http://www.ifeu.org/english/index.php?bereich=abf&seite=klimarechner) accessed 14 July 2015.

IGES, 2013, User Manual - Estimation tool for GHG emissions from municipal solid waste management in a life cycle perspective, Japan (http://pub.iges.or.jp/modules/envirolib/upload/4273/attach/User_Manual_for_Simulation-Version_II_%28edited%29-01_Oct_2013.pdf) accessed 14 July 2015.

India, 2012, Second National Communication to the United Nations Framework Convention on Climate Change.

Indonesia, 2010, Indonesia Second National Communication Under The United Nations Framework Convent ion on Climate Change (UNFCCC).

Indonesia, 2015, 'Questionnaire on waste inventory compilation'.

IPCC, 2000, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (http://www.ipcc-nggip.iges.or.jp/public/gp/english/index.html) accessed 14 July 2015.

IPCC, 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html) accessed 14 July 2015.

Kazakhstan, 2014, National Inventory report to UNFCCC 1990-2012.

Mexico, 2012, Actualización del Inventario Nacional de Gases de Efecto Invernadero 1990--2010, para el sector de Desechos (http://www.inecc.gob.mx/descargas/cclimatico/2012_estudio_cc_invgef6.pdf) accessed 15 July 2015.

Namibia, 2014, First Biennial Update Report of the Republic of Namibia under the United Nations Framework Convention on Climate Change (UNFCCC) November 2014.

Romania, 2014, Romania's Greenhouse Gas Inventory 1989-2012.

South Africa, 2009, Greenhouse Gas Inventory South Africa 1990 to 2000 Compilation under the United Nations Framework Convention on Climate Change (UNFCCC) National Inventory Report.

South Africa, 2014, GHG Inventory for South Africa 2000-2010.

Tunisia, 2014, Contribution au Premier rapport biennal de la Tunisie.

Tunisia, 2015, 'Questionnaire on waste inventory compilation'.

UNEP and DTU, 2015, 'CDM/JI pipeline analysis and database' (http://www.cdmpipeline.org/) accessed 16 June 2015.

UNFCCC, 2014, Handbook on Measurement, Reporting and Verification for developing Country Parties, UNFCCC Secretariat (http://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/non-annex_i_mrv_handbook.pdf) accessed 14 July 2015.

US EPA, 2007, Landfill Gas Modelling (http://www.epa.gov/methane/lmop/publications-tools/index.html) accessed 14 July 2015.

Vietnam, 2014, National Inventory Report of Vietnam 2010, Department of Meteorology, Hydrology and Climate Change.

Vietnam, 2015, 'Questionnaire on waste inventory compilation Vietnam'.

World Bank, 2012a, User Manual, Data collection tool for urban solid waste management (http://siteresources.worldbank.org/INTUSWM/Resources/463617-1202332338898/User-Manual-Data-Collection-Tool-for-SWM.pdf) accessed 14 July 2015.

World Bank, 2012b, What a waste: A Global Review of Solid Waste Management (http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:23172887~pagePK:210058~piPK:210062~theSitePK:337178,00.html) accessed 14 July 2015.

World Resources Institute, 2015, Climate Analysis Indicators Tool, WRI, Washington, DC (http://cait2.wri.org/) accessed 9 June 2015.

Annex I. Countries included in the study

Table 7-1: Information on countries included in the analysis

	Region					Process		IPCC GL	Subcategories					Sources	
	Africa	South-East Asia	Central Asia	Latin America	Annex I	Uncertainties	QA/QC		Solid Waste Disposal	Wastewater (domestic)	Wastewater (industrial)	Incineration/open burning	Biological Treatment	Questionnaries	Available submissions under UNFCCC
Armenia			X			X	X	2006	X	X		X			NC3 & NIR 2014
Brazil				X				Mixed	X						NC2 2010, BUR 2014
Bulgaria					X		X	GPG 2000	X	X			X	X	NIR 2014
Chile				X				2006	X	X	X		X	X	NC2 2011, NIR 2014, BUR 2014
China		X						Mixed	X						NC 2012
Germany					X			Mixed					X		NIR 2014
Ghana	X							1996						X	NC & NIR 2011
India		X						2006	X		X				NC2 2012
Indonesia		X						2006	X					X	NC2 2010
Kazakhstan			X				X	Mixed	X						NC2 2009, NIR 2014
Mexico				X				2006	X			X	X		NC5 & NIR 2012
Namibia	X						X	2006	X	X	X				NC2 2011, BUR 2014
Romania					X		X	GPG 2000	X						NIR 2014
South Africa	X					X	X	2006	X	X					NIR 2009, NC2 2011, NIR 2014, BUR 2014
Tunisia	X					X	X	2006	X			X	X	X	NC2 2014 & BUR 2014
Vietnam		X						Mixed	X	X	X	X		X	NC2 2010, NIR 2014 & BUR 2014

Notes: The table only shows which source categories have been analysed for a country for the preparation of this report. Most of the countries report emissions from all categories; the absence of a cross does not imply that a country does not report in that category.

Source: Compilation by Öko-Institut

Annex II. Useful data and information sources

IPCC Guidelines

Revised 1996 IPCC Guidelines: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html

2000 IPCC Good Practice Guidance: http://www.ipcc-nggip.iges.or.jp/public/gp/english/index.html

2006 IPCC Guidelines: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

UNFCCC documents

Biennial update reports:
http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php

National Communications and Inventories:
http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php

Annex I inventories:
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

UN population data

Total population from 1950 onwards: http://esa.un.org/unpd/wpp/Excel-Data/population.htm

Urban and rural population data from 1950 onwards: http://esa.un.org/unpd/wup/CD-ROM/
and http://esa.un.org/unpd/popdev/urpas/urpas2014.aspx

Models and default values for different parameters

World Bank 2012: "What a waste" Country-specific default data on waste generation, composition, treatment:
http://go.worldbank.org/BCQEP0TMO0

IFEU Solid Waste Management – GHG emissions calculator: Calculator to estimate emission reductions from solid waste disposal for different management options: http://www.ifeu.org/english/index.php?bereich=abf&seite=klimarechner

Landfill gas modelling tools: Country-specific default data for waste composition for Latin American countries:
http://www.epa.gov/methane/lmop/publications-tools/index.html

IGES Estimation tool for GHG emissions from municipal solid waste management in a life cycle perspective:
http://pub.iges.or.jp/modules/envirolib/upload/4273/attach/User_Manual_for_Simulation-_Version_II_%28edited%29-01_Oct_2013.pdf

US EPA Waste Reduction Model WARM: http://epa.gov/epawaste/conserve/tools/warm/index.html

Institutions and programmes that provide support for capacity development for MRV of greenhouse gas emissions and mitigation actions

UNFCCC Tools and Training Materials for non-Annex I Reporting:
http://unfccc.int/national_reports/non-annex_i_natcom/training_material/methodological_documents/items/7914.php

UNFCCC Capacity building: http://unfccc.int/cooperation_and_support/capacity_building/items/1033.php

UNFCCC CGE Training Materials for the Preparation of National Communications from Non-Annex I Parties:
http://unfccc.int/national_reports/non-annex_i_natcom/training_material/methodological_documents/items/349.php

NFCCC CGE Training Materials for the Preparation of Biennial Update Reports from non-Annex I Parties:
http://unfccc.int/national_reports/non-annex_i_natcom/training_material/methodological_documents/items/7915.php

GIZ International Partnership for Mitigation and MRV: http://mitigationpartnership.net/capacity-building

UNDP Low Emission Capacity Building Programme:
http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/focus_areas/climate_strategies/undp_projects_thatcontributetogreenlecrds/national_sub-nationalstrategies/low_emission_capacitybuildingprogramme.html

Note: All internet links were checked at time of publication.

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15

E climate@giz.de
I www.giz.de/climate